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Salida.

To the average Eastern traveler Salida is familiar as one of the most beautiful and charming little towns in Colorado where he has to stop if he wants to take the next morning's train over the Marshall Pass to Salt Lake and where he may ascend Tenderfoot Hill right across the station in the vain hope to be considered no longer a tenderfoot. To the metallurgist the Salida smelter of the Ohio & Colorado Smelting & Refining Company conveys the idea of efficient and progressive management. The article published elsewhere in this issue on sinter-roasting with Dwight-Lloyd machines at Salida should prove particularly interesting, as it is, we believe, the first authentic description of this pioneer plant using the Dwight-Lloyd system. But this note cannot be closed without mentioning the name of F. D. Weeks, who did this pioneer work when he was smelter superintendent at Salida. Nor was it by any means his first big pioneer work; other smelters tell similar stories of him. Now more than ever men of his type are needed who, on the basis of scientific training and wide practical experience, have the courage to form a metallurgical conviction and have the greater courage and the engineering ability to transform their idea into a reality.

The Perkin Medal.

In this issue will be found a full report of the presentation of the sixth impression of the Perkin medal to Mr. Herman Frasch at the meeting of the Society of Chemical Industry on Jan. 19, in New York. The evening was as pleasant, instructive, and inspiring as any of the former presentations which have become such a charming annual feature in chemical life in New York City. The Perkin medal is now an institution—a live institution in the full sense of the word—and a brief sketch of its beginnings and history and a word on its future prospects may not be amiss on this occasion.

The fiftieth anniversary of the epoch-making discovery by William Henry Perkin of the dye-stuff "mauve," by which the foundation was laid for the now immense coal-tar industry, was fitly celebrated in 1906. Sir William Perkin came himself in the autumn of that year from England to New York to take part in the celebration which turned out a splendid success and proved especially the existence of a strong esprit de corps holding together chemical scientists, engineers, and manufacturers. It was but natural to try and find some way of preserving this spirit of united American chemical democracy.

Thus the New York section of the Society of Chemical Industry decided to found the Perkin medal, which should commemorate the inventor of mauve and act as a stimulus to American chemical research and invention. The first impression of the Perkin medal was presented by Dr. Wm. H. Nichols to Sir William Perkin on the occasion of the dinner at Del-

monico's on Oct. 6, 1906, which was the climax of the jubilee of the coal-tar industry on this side of the Atlantic.

Sir William Perkin died on July 14, 1907. The Perkin medal is to live. It is being awarded every year to a chemist residing in America for achievements of high value in applied chemistry. The modus of awarding the medal has been wisely chosen to represent the spirit of American chemical democracy. According to its constitution the Perkin Medal Committee is made up of representatives of the three large chemical organizations in this country—the Society of Chemical Industry, the American Chemical Society, and the American Electrochemical Society. This committee meets to consider and discuss the various names proposed by the above and other chemical organizations of this country and then makes the award. The first meeting of the committee was held on Dec. 16, 1907, and ever since the Perkin medal has been presented at the February meeting of the New York section of the Society of Chemical Industry to a distinguished American chemist as a "beautiful token of the appreciation and affection of his fellow-chemists."

In 1908 J. B. Francis Herreshoff was the recipient—"an engineer by birth and a chemist by education"—combining mechanical engineering ingenuity and chemical science, as evidenced by his work in electrolytic copper refining and in the contact process of sulphuric acid, and by the design of the roasting furnace known by his name.

In 1909 Arno Behr was selected for his valuable work in the glucose industry, thus representing the great American industry of corn products.

In 1910 Edward Goodrich Acheson was awarded the medal as the beloved representative of American electrochemical industries—"pathfinder, conductor, switchman — everything" in the foundation of the industries of carborundum, artificial graphite, siloxicon, silicon, and now with deflocculated graphite entering resolutely into the field of applied colloid chemistry.

In 1911 another distinguished electrochemist was chosen, Charles M. Hall, whose name is forever interlinked with the aluminium industry.

And now in 1912, Herman Frasch has been the recipient for his wonderful work in oil refining and sulphur mining.

What a record of the Perkin medal and what a record of achievements of American chemists without the end yet being in sight. The Perkin medal has been on trial, so to speak, for the past six years and has not been found wanting in giving ever-fresh inspiration to American chemists. The selection of a man to be honored by the award of the Perkin medal is not an easy one and the committee has grave responsibilities. That it is a joint committee of three national societies has done more than anything else to make it truly representative. There cannot be and will not be a lowering of the standard that has been set. And fortunately every year the fact manifests itself again that, for some time at least, there will be no difficulty in finding men worthy of the honor to receive the medal which bears the name of the great founder of the coal-tar industry.

As long as this is the case the Perkin medal cannot fail to give inspiration to all who have at heart the future of American chemistry—most of all to the young American chemist. Once a year, at the Perkin medal presentation night, he may leave aside school books' wisdom and may listen to a man who has put up to Nature questions on some of its secrets in his own way and has received an answer. To listen to such a man means to get into direct contact with Mother Earth.

The Analogy Between a Blast Furnace and a Modern Building on Fire.

The appalling fire which destroyed the Equitable Building in New York City on Jan. 9 marks the end of an historic structure. The general press has lamented over the passing of so much that was of interest in connection with the building, like the Lawyers' Club, the original downtown lunch club, and the classical place where the formation of the "Steel Trust" was first conceived. The fire proved conclusively that a building of brick, stone, steel, and concrete can be destroyed by fire, and many morals have been pointed out that architects and city builders should draw from the disaster. At this place the fire may be subjected to a discussion from the standpoint of a metallurgical engineer.

For it is not at all a stress on the imagination to compare the Equitable Building on fire with a blast furnace. Like a blast furnace, the entire structure had a refractory casing. Like a blast furnace, it contained a lot of combustible material, for the woodwork, books and papers had a high calorific value. While there was no forced blast, yet the West wind delivered a large volume of air through the windows and doors, which can be regarded as the tuyeres. This blast was reinforced by the suction of the burning gases. Finally, the whole structure was effectively water-cooled by the spray and streams of scores of fire engines, and the opinion has often been expressed that an iron blast furnace should be cooled by a stream of water from top to bottom.

It is, of course, a mathematical truth that as any metallurgical furnace increases in size the percentage of heat lost by radiation decreases, for the amount of generated heat increases as the cube of any linear dimension and the amount of heat given off to the surroundings by radiation and convection increases only as the squares of any linear dimensions. It follows directly that it is much easier to attain a high temperature in a big furnace than in a small furnace. The same identical reasoning applies to the Irishman's "fireproof building on fire." With a large building the heat generated by the combustion has a comparatively smaller chance to get out and consequently the temperature attained is correspondingly higher. Practical people like the firemen and underwriters do not have the exact theoretical knowledge to confirm their practical experience or the erection of "fireproof" buildings would not have been carried to such an extreme.

The fear has often been expressed that other buildings in the downtown district are dangerous and all the more because they are called fireproof. With the great number of people congested in the lower part of Manhattan Island a general conflagration suggests sickening and frightful possibilities. The place is like a rabbit-warren and should be made like a rabbit-warren completely. All the large buildings should communicate with each other on every fifth floor and should also have communicating cellar passages. There should also be steel bridges at convenient intervals and on different levels so that

people could pass from a building on one side of the street to the other side at the higher levels.

There should be an abundance of the modern chemical fire-extinguishers which use carbonated water or carbon tetrachloride. These are most efficient to prevent incipient fires. It would be still better to have an entire system of chemical automatic extinguishers—something like the sprinkler system, but making use of the property that carbon dioxide has to prevent combustion.

Modern applied science has increased the risks of life in new ways, while it has, of course, diminished the risk of life in old days. There was a time when epidemics were havoc-workers. But bacteriology and hygiene seem to preclude this at present. We no longer are afraid of Indian raids, for the rifle has caused the Indians to be peaceful. But the danger from fire in the center of a modern city is terrible, for fireproof buildings are misnamed. It is true, however, that modern science has given us means to prevent the disasters. Unless proper regard is given to the fact that it is wrong to place combustible stuff in a structure that is refractory without efficient and perfect means for confining the fire to an insignificant space, some day the world will wake up and read about an American disaster that will be as horrible as it will be historic. With the idea fixed in the mind of the nation that a disaster is possible, but that it will be impossible if proper modern scientific means of prevention are employed, the battle is half won.

Federal Aid to Mining and Metallurgy.

Considerable misapprehension seems to exist regarding the future relations of the Bureau of Mines to the metallurgical industry. In Colorado, particularly, a great deal of misdirected energy has been expended with the approval and encouragement of men who, judging from their positions, should be better informed as to the facts and possibilities. Meetings have been held at which resolutions have been adopted, which plainly show prejudice or a failure to comprehend the situation. In view of the fact that there is a prospect of federal co-operation in the metallurgical industry, it may not be amiss to consider what, in all probability, may and may not be expected.

The keynote of the agitation has been: "Give us some method of treating our low-grade and complex ores." We omit reference to "millions of tons," which is a stock phrase lightly used, and are also cognizant of the abuse of the term "complex ore." Without decrying the desirability of finding methods of ore dressing and metallurgy applicable to some of our Western ores, we must not lose sight of the fact that vast progress has been achieved privately in the last few years, and that time and money are being expended constantly by our large companies in an endeavor to adapt further improvements. Judging from the touching appeals made for government aid, one would imagine that private enterprise is dormant, and that heroic measures are immediately necessary if the industry is to be saved from ruin. A moment's thought will show the fallacy of this attitude. Private investigation has been responsible for late advances in ore treatment, and those who place their reliance in the paternal aid of the government seem to forget that, in the event of active federal co-operation, the government probably would obtain, if possible, the services of men now engaged privately and familiar with the industry.

Prolonged metallurgical experiment costs money, and no doubt it is on this score that federal aid is urged. Elaborate experimentation is not the proper field of labor for small mining companies. It is rather for them to follow the blazed trail, adopt proved methods, and keep pace with sound improvement. Private research by large companies and wealthy individuals will always have a place in metallurgical progress, but the results in a majority of cases will be private property. The Bureau of Mines could, no doubt, find a field for research and investigation of fundamental problems, the results of which would be public property, useful to the entire industry and to the nation at large.

While misapprehension has been general regarding the function of the Bureau of Mines, the greatest stumbling block seems to have been the "government ore testing plant." The impression seems to prevail that the one thing necessary for an immediate revival and extension of mining prosperity is to have the government build and equip "ore testing plants" in various parts of the West.

Here, again, a sane conception of the purpose of an ore testing plant will clarify the view of the whole matter. An ore testing plant conveys the idea of a mill building equipped with various machines and devices embodying known processes of ore treatment. We have many such plants fostered by private enterprise and run for profit. It has been possible for years to have ores tested at these plants by various known methods or combinations of processes. With this in mind, it is difficult to see how a similar plant operated by the government would prove an open sesame to widespread mining prosperity. In fact, it could not.

There are two other functions of a testing plant, or rather, of a laboratory for metallurgical research, neither of which would encroach on private enterprise. First, after a broad survey of metallurgical progress, the merits of certain propositions might be investigated, the soundness of their mechanical and chemical principles reviewed, and their applicability broadly determined. Second, original research in fundamental problems might be undertaken. There are many of these, and the scientific results obtained would be of value to inventors or others seeking to make specific application of known scientific facts and data.

Neither of the foregoing propositions requires a commercial "testing plant," and the location of the laboratory need be of no particular concern. The West sought the establishment of the Bureau of Mines, and desires to receive some benefit from it, particularly in the metallurgical industry. It must be realized, however, that the work of the Bureau is to be along broad lines, useful to the entire country. There are also needed soundness in the representations to the Bureau and good judgment in the requests for aid; for the Bureau itself must be guided in a large measure by the representations of the constituency which it is to serve. If we have but a hazy idea of our needs we can expect no definite results from those less well informed. Finally, if the West believes in the ability of the head of the Bureau, as it does, it should make a united effort to get the necessary appropriations, and leave their final disposal to the judgment of Dr. Holmes, who has shown a commendable desire to familiarize himself with the West and with the needs of the West.

American Electrochemical Society.

The annual meeting of the American Electrochemical Society will be held early in April in Boston, Mass. The exact date has not yet been fixed.

One of the features of the professional sessions will be a symposium of papers on "electric conduction," the subject to be treated from the broadest and most fundamental viewpoints. This is being arranged at present by the president, Dr. W. R. Whitney.

Further details will be given in our next issue.

The Chicago section of the American Electrochemical Society held a highly successful midwinter meeting on January 5, at the rooms of the Western Society of Engineers, the topic of the evening being "the fixation of atmospheric nitrogen." Mr. L. L. Summers dealt in an interesting manner with the general problem and Mr. E. R. Wolcott presented an able paper on the special features of the subject. An active and prolonged discussion followed. The attendance was excellent, the local members of the American Chemical Society being present as guests.

American Institute of Mining Engineers.

The annual meeting of the American Institute of Mining Engineers will be held in New York City from Feb. 19 to 21.

Important issues bearing on the future development of the Institute will be decided at this meeting. These relate to the proposed re-classification of membership, to the proposed redistribution of the dues, and to the proposed change of name of the Institute. The name is proposed to be changed to "American Institute of Mining and Metallurgy."

It is the purpose hereafter to make the annual meeting of the Institute the most important gathering, professionally and socially, of the year and great attempts are being made by the New York members to make the meeting in February a brilliant success.

At a meeting of the New York section held on January 5th, Dr. Gardner F. Williams, of Washington, D. C., delivered an illustrated lecture on the South African Diamond Fields.

Symposium of Papers on Research.

A joint meeting of the New York Section of the American Electrochemical Society, the American Chemical Society, and the Society of Chemical Industry will be held in the Chemists' Building, 50 East Forty-first Street, New York City, on Feb. 9. The meeting will be devoted to a symposium of papers and discussions on the subject of "research."

The meeting will be held under the auspices of the New York Section of the American Electrochemical Society and will be opened by an introductory address of its chairman, Mr. Elmer A. Sperry.

The following papers will be presented:

The Commercial Aspect of Research, by Dr. Charles F. Lindsay, of the Remington Arms-Union Metallic Cartridge Company.

Research in Technical Laboratories, by Dr. Arthur M. Comey, of the E. I. du Pont de Nemours Powder Company.

Independent Research Laboratories, by Mr. P. McN. Bennie, of the FitzGerald & Bennie Laboratories.

Research in the Physics and Chemistry of Modern Roentgen Ray Practice, by Dr. W. D. Coolidge.

Dr. Leo H. Baekeland, Dr. Peter Cooper Hewitt, Dr. Edward Weston, Dr. W. R. Whitney and other prominent speakers are expected to participate in the discussions.

Since there seems to exist some confusion concerning the date of the meeting, it may be repeated that the correct date is Friday, Feb. 9.

Electric Steel Furnace.

About the recent industrial development of the Stassano electric steel furnace (the technical features of which were described in detail in an article by Major E. Stassano in our Vol. VI, p. 315, August, 1908), the following information will be of interest.

The Societa Forni Elettrici Stassano went into liquidation in December, 1909, and this enabled Major Stassano to recover, as being entitled thereto, his own patents covering the electric arc furnace of his type, which patents the company had been unable to use to advantage. Since 1909 Major Stassano has been the sole owner of the patents and since then up to the present time he has made the following installations.

For the Societa Elba one 250-kw Stassano furnace is in operation at Porto Ferrario and an 800-kw Stassano furnace is to be installed in one of its works in Liguria.

For the Milan steel foundry, Fonderia Milanes d'Acciaio, one 250-kw and two 100-kw Stassano furnaces have been installed; for the J. J. Hoehn concern two 250-kw furnaces, this plant being located at Odessa; for the Electro-Flex Steel Co., Ltd., of Newcastle-on-the-Tyne, three 250-kw furnaces. A steel works is also being installed in Dunston-on-the-Tyne exclusively with Stassano furnaces.

After several years ago the Italian War Department had adopted the Stassano furnace for their Artillery Construction Shop. The Italian Navy Departemnt will shortly likewise adopt it for the Navy Yards.

Washington Meeting of the American Chemical Society.

Again the American Chemical Society has broken its own record of attendance at the meeting held in Washington from December 27 to 30, 658 members and guests registered, and probably 700 were present. Over 250 papers were presented at the meeting.

The meeting opened on Wednesday, December 27, with a joint session of the Section on Chemical Education and the Division of Physical and Inorganic Chemistry, at which the following four papers were presented:

A. A. Noyes, on the teaching of physical chemistry.

W. D. Bancroft, on physical chemistry in the introductory course.

H. C. Jones, on the introduction of physicochemical conceptions in the early stages of the teaching of general chemistry.

J. Howard Mathews, on some applications of color photography in the teaching of physical chemistry.

In the afternoon the address of vice-president Frankforter, of Section C, entitled "the resins and their chemical relations to the terpenes," was delivered before a large audience and was followed by an address by Chairman H. P. Talbot, on the subject "privileges and responsibilities of the chemical analyst." Following Dr. Talbot, Dr. A. L. Voge, of the Library of Congress, read a paper on "Ostwald's proposed International Institute of Chemistry."

Throughout the week the Society's Divisions of Agricultural and Food Chemistry, Biological Chemistry, Industrial Chemists and Chemical Engineers, Fertilizer Chemistry, Organic Chemistry, Pharmaceutical Chemistry, Physical and Inorganic Chemistry, and the Chemistry of India Rubber, held meetings in rooms especially assigned to them.

Some 500 were present at the "smoker" on Wednesday evening, which was as much enjoyed as any that preceded it.

On Thursday evening Alexander Smith, president of the Society, delivered his presidential address, entitled "an early physical chemist," and was followed by an interesting lecture by Frank B. Kenrick and H. E. Howe, consisting chiefly of illustrations by means of the lantern of the effect of tempera-

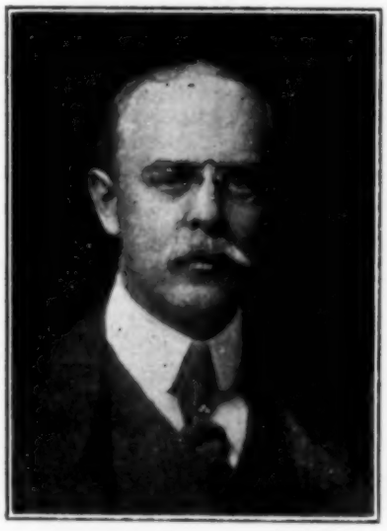
ture, pressure, concentration, surface tension, osmotic pressure, etc., on reactions in heterogeneous systems.

A feature of the divisional meetings was the Symposium on Mineral Wastes and their Conservation, held before the Division of Industrial Chemists and Chemical Engineers on Friday. The following papers were presented:

J. A. Holmes, on carbon waste.

W. H. Bassett, on zinc losses in brass manufacture and the need of special alloys for special uses.

W. R. Whitney, on new uses to reduce abuses in conservation.



ARTHUR D. LITTLE,
PRESIDENT AMERICAN CHEMICAL SOCIETY

A. V. Bleininger, on wastes in the ceramic industry.

A. D. Little, on the abuse of brand.

F. K. Cameron, on waste and conservation of potash and phosphoric acid.

F. G. Cottrell, on sulphur fumes and flue dust.

Charles L. Parsons, on miscellaneous mineral wastes.

The Division of Pharmaceutical Chemistry held a Symposium on Drug Assaying on Friday morning and on Friday afternoon a joint meeting of the Society of Biological Chemists was held with the biological chemists of the American Chemical Society.

The secretary's report showed an increase of members of over 500 for the year, the Society's membership standing on December 1, at 5603.

At the meeting of the Council on Tuesday afternoon and evening the Biological Section of the Society was authorized to form a Biochemical Division, electing its own officers, and two new Local Sections were formed; one at Detroit and one at New Haven.

Interesting reports were received from the Committee on Standard Methods of Analysis and from the Committee on Patent and Related Legislation.

It was voted to donate the library of the American Chemical Society to the New York Chemists' Club on condition that members of the Society have ready access thereto.

The question of the time of the annual meetings of the Society was vigorously discussed, many members favoring a change from the winter season to Easter week, and a committee was appointed to take this into consideration and report to the Council.

The election of the following officers for 1912 resulted as follows: A. D. Little, president; C. L. Parsons, secretary; A. P. Hallock, treasurer. The new president, Mr. Arthur D. Little, is the well-known and distinguished chemical engineer and expert of Boston.

New Chemical Course at College of the City of New York.

The Board of Trustees of the College of the City of New York has authorized the opening of courses in the Department of Chemistry (Prof. Chas. Baskerville, Director) to mature and properly qualified applicants who may desire work in chemistry, without pursuing the full curriculum leading to a degree. Special courses are offered in analytical, industrial, organic, physical chemistry and electrochemistry, with opportunities for investigation.

The Western Metallurgical Field.

Inspiration Consolidated Copper Company.

The consolidation of the Live Oak and Inspiration copper properties which was announced in our last issue has taken definite form in the organization of the Inspiration Consolidated Copper Company, capitalized at $30,000,000 in 1,500,000 shares of $20 each. The terms of stock exchange have been announced to old stockholders in the Live Oak and Inspiration companies. Live Oak stockholders may exchange one share of old stock for two in the new company, or can receive $40 per share for their Live Oak stock. Inspiration stockholders have the alternative of selling their stock for $10 per share, or of exchanging two shares of old stock for one of new. This offer was to expire on the 29th of January. Up to the same date stockholders were to be given the opportunity of purchasing 6 per cent 10-year bonds, convertible into stock at $25. The bond issue is in the amount of $6,000,000.

The total amount of ore now developed in both properties is placed at 45,300,000 tons of 2 per cent copper content, or a total of 1,812,000,000 lb. of copper. The recovery of metal from this ore, based on 80 per cent extraction, will amount to 1,449,600,000 lb. Based on the estimates obtained from operations of other copper companies working disseminated deposits, it is thought that the cost of copper production will be about 9 cents per pound. A mill of 7500 tons daily capacity is tentatively planned, and it is thought that the new company will add from 65,000,000 to 70,000,000 lb. of copper to the annual output of the United States.

Tonopah in 1911.

The Tonopah district, Nevada, attracted considerable attention last year owing to the extensive mining and milling operations that were under way and planned. The district had five mills in operation, using modifications of amalgamation, concentration and cyanidation processes. Stamps and tube mills are used as grinders, while in cyanidation some of the latest and best practice has been developed there. The following tables are compiled from data given by the Tonopah *Miner*, and show at a glance the magnitude of operations.

Production and Values.

Company.	Tons.	Gross Value.
Tonopah Mining	173,600	$3,572,000
Tonopah Belmont	114,500	3,091,500
Montana Tonopah	52,500	761,250
Tonopah Extension	51,000	663,000
West End Cons.	13,350	318,750
Midway	2,100	52,500
MacNamara	1,090	27,250
Total	408,140	$8,486,250
Increase over 1910	45,247	950,187

Mills in Operation.

Company.	Stamps.	Tons Capacity.
Tonopah Mining	100	500
Belmont	60	300
Montana	40	150
Tonopah Extension	30	145
West End Cons.	20	125
Total	250	1220

Mills under Construction.

Company.	Stamps.	Tons Capacity.
Belmont	60	500
MacNamara	10	50
Increase in 1912	70	550

Mason Valley Smelter.

On the sixth of January the new smelter of the Mason Valley company, at Thompson, Nevada, was blown in. Con-

struction of this plant began in November, 1910, and cost about $1,000,000. During the period of smelter construction the mines owned by the company and by the Nevada Douglas Copper Company, were developed so as to provide a continuous supply of ore. On December 2 last, the first load of ore was sent to the smelter, and on the 10th of January, it was reported that ore was then being received at the rate of 700 tons per day.

The threatened litigation over smoke damage with which the company was confronted, has not amounted to anything, and it is expected that, except for the trouble caused, it will not seriously affect operations. The location of the smelter and the direction of the prevailing winds are both favorable to a rapid diffusion of smelter fumes over a country that is not occupied by agriculturists. Furthermore, the laws of Nevada are partial to the operation of the mining and smelting industries, as it was demonstrated years ago that the greatest source of wealth in the state lay in the mines. Hence, every effort has been made to encourage mining and allied industries.

Zinc in Montana.

Those conversant with conditions in Butte, predict for that district a remarkable future in the production of zinc. When W. A. Clark disposed of his copper mines to the Amalgamated interests he retained his zinc properties, and these bid fair to rival the copper mines in size of ore bodies and production of metal. The Butte & Superior company also developed immense bodies of zinc ore in the Black Rock claim adjoining Mr. Clark's Elm Orlu claim.

Several months ago Mr. Clark's concentrating works at Butte burned, and at that time zinc production from the Elm Orlu ceased. The Butte & Superior has operated for some time the old Basin Reduction Works, at Basin, Mont., but a new plant is now under construction which will employ the ordinary methods of wet concentration and, in addition, a system of flotation. Owing to certain commercial transactions with regard to a claim for almost $160,000 against the Basin Reduction works, it has been rumored that Mr. Clark is to acquire that plant and mill his zinc ores there. But the Butte & Superior lease on the plant holds until June 30, and in the event that Mr. Clark did acquire the old plant, he could not begin operations until July 1. In spite of the persistence of the rumor, it is difficult to believe that Mr. Clark will try to use the old Basin plant instead of building a modern concentrating mill. The Basin mill is ill-adapted to the concentration of zinc ores, and it is an open secret that the Butte & Superior company has sustained enormous tailing losses during its period of operation. In view of the future importance of the zinc business in Montana, and the great improvement that can be made on the Basin plant, it would seem that the lead of the Butte & Superior ought to be followed and a modern plant erected by Mr. Clark.

Lead and Zinc in the Northwest.

The fact that international boundary lines have no reference to natural geographical or geological conditions gives rise to local economic complications that are not always easy to solve. An incident in point is seen in the lead and zinc deposits of British Columbia, in which citizens of the United States are interested, and the further desire of the owners to permit the free entry of Canadian lead and zinc ores into the United States. The mining men's organization of Spokane, Washington, has recently addressed itself to the task of securing reciprocal relations between Canada and this country, whereby the duty will be removed from imported lead and zinc ores. They argue that the cost of production of metal in Canada is greater than in the United States; that much American capital is invested in Canadian mines; and that the tariff regulation regarding ore is of no advantage to the United States and serves to restrict industry. The matter is being taken up by Washington's political representatives.

The Montana Smelting Company is a new corporation recently organized to take over the interests of the Pacific Coast Smelting-Refining-Mining Company. It is reported that the new company will erect a lead smelter at Libby, Montana, and construct a railroad from that point to the Snowshoe mine in Idaho.

Metal Production Statistics for 1911.

The preliminary estimates of metal production in the various states for 1911 have been issued by the U. S. Geological Survey, and can be obtained in full on application to the Survey.

There was a slight decrease in gold production in the United States as compared with 1910, but silver production showed an increase of over 2,000,000 fine ounces, due largely to increased operations in copper and lead mining. The following states showed decrease in gold output: Arizona, California, Colorado, Montana, Oregon, Washington, and Alaska. Increases were noted in Idaho, Nevada, New Mexico, South Dakota and Utah. The total gold production for the United States is estimated at $96,233,528; silver at 57,796,117 fine ounces. The average price of silver in 1911 was 53 cents, a decrease of one cent compared with 1910.

The 1911 output of copper exceeded that of 1910, and nearly equalled the record production of 1909. According to statistics and estimates received the output of blister copper from domestic ores was 1,091,554,000 lb. in 1911. Arizona held first place last year, but the output will hardly equal that of 1910. Montana, in second place, also will show a decrease in production, due to the policy of curtailment inaugurated by the companies in the Butte district. The other copper producing states rank as follows: Michigan (decrease), Utah (increase), Nevada (increase), California (decrease), Alaska (increase), Tennessee (increase), Colorado (decrease), Idaho (decrease), New Mexico (increase).

Considerable increase in mine production of lead and zinc was shown in 1911. Some of the older producing districts showed slight decreases, but in Colorado and Montana the production of zinc ore was much increased. Lead fell off slightly in Colorado, but increased 50 per cent in Montana. The Joplin district fell off slightly in zinc concentrates, but gained in lead.

Among the minor metals, quicksilver was produced in larger quantities in California, but fell off in Nevada and Texas. In Arizona, Washington, Oregon and Utah there was no production. Nevada is credited with the erection of one new 25-ton furnace by the Mercury Mining Company, at Ione. The total domestic production was 21,821 flasks of 75 lb. each, which is a gain of 1220 flasks over 1910.

There was considerable activity in tin mining in the placer fields of Alaska. Ordinary placer operations gave way to dredging, and from 80 to 100 tons of concentrate was recovered by this method. Work on cassiterite-bearing lodes was encouraging.

There was sharp falling off in the production of tungsten in 1911, owing to the decrease in the market for tool steels. Only 1125 tons of 60 per cent concentrate were marketed during the year, which is about two-thirds of the amount produced in 1910. The Boulder county, Colorado fields gave the largest domestic production, amounting to 740 tons, which is only about one-half the usual production. California was second, and smaller amounts were produced in Arizona, Nevada, Idaho and Washington.

The Non-Ferrous Metal Market.

The intervention of the holiday season had its usual effect on the metal markets, and during the last week of December and the first week of January the usual retarding influence was noticed. Copper has continued to rise since our last report, and there has been a slight flurry in tin, but otherwise the markets have been without feature.

Copper.—The bulk of the business done was for foreign

interests, and the domestic purchases have been comparatively light. The publication of the December statistics had the effect of lowering prices for actual sales, although the quotations remained almost stationary. The last quotations are 14.30 to 14.50 cents for Lake, and 14.20 to 14.30 cents for electrolytic.

Lead.—The market has been unchanged for several weeks, with quotations at 4.45 cents, New York, and 4.30 to 4.35 cents, St. Louis.

Tin.—The market was demoralized early in the month, but steadied later. Premiums were demanded for immediate delivery, in some cases as high as 1.5 cents per pound. The bulk of the business is for future delivery. January tin was quoted at 42 cents at last reports.

Spelter.—The difference in price for spot and future metal has been widened, and many consumers are taking advantage of the situation to stock up with metal for future delivery, thereby avoiding the necessity of paying premiums for immediate delivery. The last quotations were 6.25 to 6.40 cents, St. Louis, and 6.40 to 6.55 cents, New York.

Other Metals.—Business in aluminium has been without feature. Quotations are unchanged at 18.5 to 19 cents. Prices for antimony have been steady and business fair. Quotations range from 7⅜ to 7¾ cents for various brands. The quicksilver market is steady with prices at $43 per flask of 75 lb., New York. San Francisco prices are 50 cents per flask lower.

The Iron and Steel Market.

January has proved a disappointing month in the iron and steel market. While little if any ground has been lost, there has been no gain. Specifications for finished steel against contracts have been only fair, and not in proportion to the large volume of contracts entered in November and December. In pig iron, prices have held their own, but there have not been the advances which might have been expected in view of the advancing tendency displayed by steel products in December.

The disappointment in January business was due largely to the fact that high hopes were entertained. The improvement in buying in November, with an improvement even in prices in December, followed after such a long period of indifferent business that a strong reaction occurred in sentiment and the trade could see nothing but continued improvement.

Now that a period of relative quietness has intervened, the November-December improvement in trade can be studied in the retrospect with clearer perception. There were two influences: first, there was recognition by all buyers that the long continued decline, practically uninterrupted by advances during almost two years, had brought prices of finished steel products to a very low level, at which it was perfectly safe to make contracts for as long a period as the mills would permit, and to specify with some freedom against those contracts for immediate delivery; second, there was a definite movement on the part of certain railroads to buy cars, this movement being held in some well-informed quarters to have been fostered by important financial interests. The car buying was heaviest in November, while contracting was heaviest late in November and early in December, while almost throughout December there was heavy specifying.

The net result was that the mills entered the new year with a very comfortable tonnage sold on contracts for the first quarter, many contracts extending through the second quarter, while there were specifications on books in the case of bars, plates and shapes, which would run the mills for six or eight weeks. The car shops started the year with orders for more than 75,000 cars on their books, which would involve practically full operation of the car shops for about three months.

Thus fortified with actual business on books, the January quietness has not affected either prices or the rate of production. Indeed, production has increased, although but slightly. In the second half of January it has been at the rate of about 80 per cent of total capacity, against 75 per cent in November and December.

Pig Iron.

Foundry pig iron has been quiet in the past month, compared with the activity in November and December, when many consumers covered the bulk of their requirements for the early portion of the new year. The largest purchases in the Pittsburgh district were those by the Standard Sanitary Manufacturing Company, which took about 3000 tons, for first quarter delivery to its Allegheny and New Brighton plants on the basis of $13, valley. The market stiffened slightly during the month, a few sales of small lots being made at $13.25, valley, although $13 could still be done on attractive orders. In basic iron the chief activity since last report has been through the purchases of the Pittsburgh Steel Company, which on the last business day of the old year bought between 10,000 and 15,000 tons for January delivery, and in January bought an equal tonnage for February delivery. This company had formerly obtained its iron on a scale contract, with monthly price adjustment. An Allegheny valley interest bought about 10,000 tons of basic, for delivery over the first half of the year, at $12.50, valley, or a shade under that figure, while 1000 tons were sold to an eastern consumer, for second quarter only, at $12.45, valley. In Bessemer iron little was done. While furnaces continued to quote $14.25, valley, a sale of 1000 tons to a foundry interest was reported at $14.10, valley, made by a broker. Southern iron was very quiet, but furnaces maintained $10, Birmingham, as a minimum, the heaviest selling for the first quarter and half of the new year having been done in November and December at an average of about $9.75, Birmingham. Several southern producers have been adhering to a minimum of $10.25 to $10.50, Birmingham. Having made heavy sales last year for this year's delivery Buffalo sellers firmed up in prices to the extent of at least 25 cents. In eastern Pennsylvania there was heavy buying during January of low phosphorus iron, at about $17 at furnace. At the close of the month the market stands quotable as follows: Southern iron, Birmingham, $10 for No. 2 foundry; No. 2X Philadelphia $14.75 to $15; No. 2 foundry, f. o. b. Chicago furnace, $14; f. o. b., valley furnaces (90 cents higher, delivered Pittsburgh) No. 2 foundry, $13 to $13.25; forge, $12.50 to $12.75; malleable, $12.75 to $13; basic, $12.35 to $13; Bessemer, $14.25.

Steel.

The unfinished steel market scored a further advance early in January, due to mills being well sold up, with specifications coming in freely, and a level was reached of $20, Pittsburgh, for billets and $21 for sheet bars, rods being $24.50 to $25. Several of the mills in the Pittsburgh district advanced forging billets to $27 or $28, Pittsburgh, although $26 could still be done. The total advance in sheet bars from the low point toward the close of November is about $2 per ton, but most of the steel now being shipped is steel which was sold at near the low point.

Finished Material.

Current prices, f. o. b. Pittsburgh unless otherwise stated, are as follows, and are firmly maintained except as to occasional shading in sheets:

Rails, standard sections, 1.25 cents for Bessemer, 1.34 cents for open-hearth, f. o. b. mill, except Colorado.

Plates, tank quality, 1.15 cents; Chicago, 1.30 cents.

Shapes, 1.15 cents.

Steel bars, 1.15 cents; Chicago, 1.25 cents.

Iron bars, 1.25 cents, Pittsburgh; 1.27½ to 1.30 cents, Philadelphia; 1.15 to 1.20 cents, Chicago.

Wire nails, base, $1.55; plain wire, 1.35 cents, base.

Black sheets, 28-gage, 1.90 cents; galvanized, 2.90 cents; painted corrugated roofing, $1.35 per square, 28-gage; galvanized, $2.50. Tin plates, $3.40 for 100-lb. cokes.

CORRESPONDENCE.

Henry Le Chatelier.

To the Editor of Metallurgical & Chemical Engineering:

Sir: The passing of the active direction of the *Revue de Metallurgie* from the hands of Prof. Le Chatelier to those of Prof. Guillet is a matter of great concern to metallurgists. However great the ability of his successor is, we cannot help regretting keenly for our own sake that we shall miss something of the influence of the older man, for till now we have had them both. Nor can we read Prof. Le Chatelier's letter, in which he announces the change in his relations, without a pang. Here again is the cry of Elijah, the deep grief of the broad and generous nature at the pettiness and selfishness of so much that forces itself on his attention.

If we measure the shortcomings of the led against the virtues of the leader we shall always have cause for despondency. But the fault is in our method of measuring. It is not with the leaders that we should compare the led of to-day, but rather with the led of ancient history. Thus read, history is an inspiration and an encouragement to those with any capacity for leadership; for though it reminds them of the great differences of level in the nature of the men of any given time, though it will not let them forget that, however equal men must be before the law, they are as noon is to twilight in their character, yet it cannot fail to assure those who will read fairly that the motives and the point of view of any given stratum of men to-day are far higher and nobler than those of the corresponding stratum in the days of Homer and of Moses. Therefore, let us be of good cheer, saying with the sage "Nevertheless, it moves."

Columbia University, New York. Henry M. Howe.

Flow of Heat Through Contact Surfaces.

To the Editor of Metallurgical & Chemical Engineering:

Sir: There is an unfortunate typographical error in the table published on page 43 of your January issue. For the first five values at the top of the second column on that page the first two columns should have been moved over to the right under their respective column headings like the rest of the table. The column of the "relative" values following these should not be in the column for the kw per sq. ft., as might appear from the error in the values above them; these relative values are correctly placed in a separate column without any heading, as they are only relative and not absolute.

Philadelphia, Pa. Carl Hering.

Gravity and Electromotive Force.

To the Editor of Metallurgical and Chemical Engineering:

Sir: I should like to call your attention to the fact that the electromotive force developed by gravity between two reversible electrodes placed one above the other is not quite so simply calculated as indicated in the last paragraph of Mr. Hering's letter in your January issue. This electromotive force has been computed by Dr. R. C. Tolman, who derives the following expression for iodine electrodes in an iodide solution (*Proc.* Am. Acad. of Arts and Sciences, Vol. 46, p. 114, 1910).

$$10^7 EF = hg\ [T_0 M_s\ (1 - v_s d) - M_I\ (1 - v_{I_2} d)]$$

where E = the electromotive force,
F is one faraday,
h is the distance between the electrodes,
g is the acceleration due to gravity,
T_0 is the Hittorf transference number of the cation,
M_s is the molecular weight of the dissolved iodide,
M_I is the atomic weight of iodine,
d is density of the solution,
v_s is the "partial" specific volume of the salt,
v_{I_2} is the "partial" specific volume of the iodine.

Of course a similar formula would hold for any reversible pair of electrodes similarly arranged.

In the article referred to the complete bibliography of this interesting subject is given.

M. deKay Thompson.

Massachusetts Institute of Technology, Boston, Mass.

Chemical Card Index of Patent Office.

To the Editor of Metallurgical and Chemical Engineering:

Sir:—In your January issue, in the editorial on the patent reform problem, etc., reference is made to our card index of chemical literature. The number of cards it contains is slightly overstated, as at the present time it contains about one and a quarter million of cards only. All that is said, however, as to the advantages to be derived from consulting it I can heartily endorse.

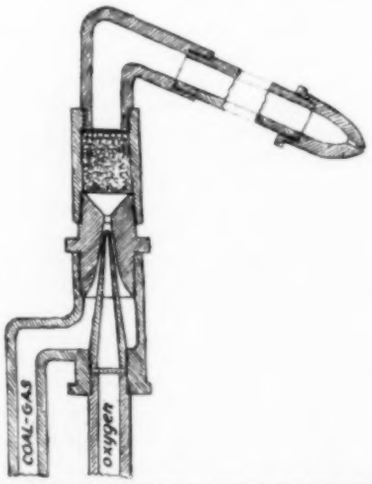
For those interested who desire to learn more about this index may I refer to two descriptive articles which have already been published in reference to it, both in the *Journal* of the American Chemical Society, viz., vol. XXII (1900), pp. 478 to 494 and vol. XXIX (1907), pp. 936 to 941? The writer is now preparing an additional article bringing the information concerning the index up to the present time. Edwin A. Hill.

U. S. Patent Office, Washington, D. C.

The First Injector Type of Blowpipe.

To the Editor of Metallurgical & Chemical Engineering:

Sir: The general belief that Fauché constructed the first blowpipe and the injector principle is erroneous. In 1893 a patent was taken out by the Manchester Oxygen Company (Brit. Pat. No. 10,554) for an oxy-hydrogen blowpipe for which the following was claimed: "A means for the utilization of the pressure in tanks of compressed oxygen in producing the oxy-hydrogen flame, or for a blowpipe or other purposes: the employment of an injector through which the oxygen or other gas is drawn and forced forward and mixed and delivered at suitable pressures for the purpose indicated."



THE FIRST INJECTOR TYPE OF BLOWPIPE

Fauché's torch as patented ten years later differs from this blowpipe only in having a coiled or zigzag shaped tube of considerable length, designed to prevent a flashback into the acetylene pipe.

New York City. A. B. C.

Excessive Heat Insulation.

To the Editor of Metallurgical & Chemical Engineering:

Sir: It has been claimed to have been found that by increasing the thickness of the thermal insulating material of steam pipes beyond a certain amount the economy of heat begins to get worse again, and that, therefore, it is actually detrimental to go beyond a certain thickness. It has also often been stated that an insulated wire cools more rapidly when heated by a current than the same wire does when it is bare. From these it has been concluded that the same would necessarily be true with electric furnace walls.

The usual interpretation of these apparently paradoxical results is that the surface exposed to the emission of the heat to the air becomes larger. It seems to the writer that this is

not the correct one, and would lead one at times to drawing incorrect conclusions, although the increased surface of course has some effect.

The correct explanation seems to be given by the figures in the table of thermal surface-resistances published by the writer in the preceding issue of this journal, p. 43. Assuming these data to be approximately correct, it will be seen that this surface resistance for a polished copper wire to the air is far greater than that from non-metallic surfaces. Hence, when a wire is insulated the heat can get out of each square inch of surface of the insulation and into the air far easier than it can get out of the copper surface when it is bare. The intimate contact of the insulation and the copper enables the heat to pass through that interior surface without encountering a great resistance, and that surface may, therefore, be neglected. Hence, if the thermal resistance of the insulation is small as compared with this very large difference in contact resistances, then an insulated wire should cool more rapidly than the bare core does.

The same argument applies to steam pipes, and explains the alleged observed result. If such insulated pipes were covered on the outside with a sheet of polished metal, the total insulation would probably be increased, and perhaps greatly, if it is hot enough. Merely polishing the outside of the insulation, say by a sheet of glazed paper, would not, in the writer's opinion, serve this purpose, as this high surface resistance seems to require that the surface be that of a good conducting body like a metal, which brings the heat there so fast that the adhering high resisting, thin air film is formed.

It, therefore, does not seem to be correct to draw the same general conclusion for furnaces as for steam pipes or insulated wires. In the writer's opinion the safest way to get a correct understanding of the results is to consider the two kinds of insulation (solid and surface) by themselves, as was done in the table above referred to and the mate to it in the earlier issue, and then combine their effects afterwards. In one case the solid resistance may be insignificant compared with that of the surface (as in boiler pipes), and in another case the reverse may be true (as in furnaces). Two such variables acting together and each varying with the temperatures and affecting each other mutually may give all kinds of combinations, which it might be very unsafe to attempt to explain as due to one cause only, namely the thickness; the end result might, however, be given in a single equation.

For well designed furnace walls the surface resistance is surely far smaller, and therefore far less important, than the solid resistance of the wall material. Hence, the insulation in general should continue to increase with an increased thickness.

Philadelphia, Pa. CARL HERING.

Electric Shaft Furnace Design.

To the Editor of Metallurgical and Chemical Engineering:

Sir:—Your December issue contains on page 669 a note on my American patent 996,492. To supplement the information there given I would like to call the attention of those interested in electric shaft furnace design also to Fig. 4 in my patent.

With electric furnaces of the resistance type with a vertical upper electrode and a reduction shaft it is a very essential point that the shaft terminate into the melting chamber so near to the base of the electrode that the new charge from the shaft always replaces the material sinking down round the electrode in such a manner as to enable the material to surround the electrode on all sides, so that no arcs can form round the base of the electrode. In order to have the electrode always embedded in the charge, the design of the shaft is important.

If the material is not fed from the shaft to the melting chamber in this way, the electrode will burn itself free, and the furnace will work as an arc furnace. The melting will then go on at the end of the electrode in the upper part of the melting chamber, and not at the bottom. In other words, the furnace then works as an arc furnace and not as a resistance furnace, and has not all the advantages of the latter type. This arrangement is also protected in my U. S. patent.

The patent rights of these furnaces belong to the Tinfos Papirfabrik and the writer.

A 500-kw furnace of this type has been working at Tinfos from January, 1910, and has proven successful in all respects.

At Notodden, Norway, is now in course of erection an iron works which will utilize 15,000 hp. from the Tinfos power plant. Furnaces of 5000 hp. capacity will be ready for operation in the Spring of 1912.

Notodden, Norway. H. BIE LORENTZEN.

Electric Reduction of Iron Ores at Trollhättan.

To the Editor of Metallurgical and Chemical Engineering:

Sir:—Mr. Otto Frick, in his article in your December issue (Vol. IX., page 631) makes some criticisms of my report on the electric furnace, erected by "Jernkontoret" for the reduction of iron ore (Redogörelse för Jernkontorets Försöksverk i Trollhättan). I take the liberty to rectify some of Mr. Frick's mistakes and hasty conclusions.

Mr. Frick says that the size of the shaft of the Trolhättan furnace has been calculated on the assumption that the proportion of volume of charge in 24 hours to volume of *shaft* equal 1.55. In my report you will find that the volume of charge in 24 hours to volume of *furnace* was taken as 1.55.

Mr. Frick points out that in the Trollhättan furnace the circulating gas is not heated outside of the furnace. This is quite correct. But such a process has been discussed by us for the past five years, without having been found practical. For this reason it has not been tried at the present plant.

Mr. Frick says that "the corresponding volume in the case of the Noble furnace has been only 7.9 cu. m., and this has proved to be more than ample." I cannot judge of the Noble furnace, but I do know that the volume of the shaft of the Trollhättan furnace, 25.55 cu. m., is *not* unnecessarily large under prevailing circumstances.

Mr. Frick gives the average temperature at the lower end of the shaft as 510° C. (maximum 682°, minimum 241°). Mr. Frick overlooks that these temperatures were measured at the inside of the brick lining of the shaft and not in the center. Later observations in the center have given temperatures up to 965° C. at the same level.

Mr. Frick says it should always be made a rule to burn the limestone outside of an electric furnace, because the use of burnt lime is economical for the process. This probably is correct in theory, but in practice we have found among other things, that it causes the burden to hang.

Mr. Frick says that no figures with regard to the temperature of the pig and the slag were given. However, the report includes a table, giving the results of 37 such observations of the temperature of pig as well as slag.

Much more could be said, as with the above I have only touched some of the more essential points.

Stockholm, Sweden. J. A. LEFFLER.

Electric Induction Furnace Design and Electric Steel Furnaces.

To the Editor of Metallurgical and Chemical Engineering:

Sir: In your December issue (page 625) Mr. F. A. J. Fitz-Gerald says that his remark that "the Roechling-Rodenhauser furnace for such sizes would be found greatly superior to other forms of induction furnaces" was an expression of an opinion based on his own experience, *so far as it goes.*

At the meeting of the American Electrochemical Society at which this matter came up, only a 30-ton furnace of my system was under consideration, designed for keeping the molten charge hot and for "killing" (dead-melting) of the steel. This

30-ton furnace had been calculated on the basis of the performance of my 5-ton furnace in actual practice.

Now Mr. FitzGerald cannot draw any conclusions on the superiority of the Roechling-Rodenhauser furnace in view of the fact that Messrs. W. Rodenhauser and J. Schoenawa in their book "Elektrische Oefen in der Eisenindustrie" (Leipzig, 1911), write as follows on page 179:

"The largest unit, so far built, of a Roechling-Rodenhauser furnace has a capacity of 8 tons and gives excellent results in actual operation in the Roechling Iron and Steel Works. This capacity, however, is by no means the upper limit for the construction or commercial use of the furnace. For furnaces up to 16 tons capacity the details of design have been definitely fixed *so that for the present this size may be considered as the upper limit for which good conditions of operation may be expected with ce tainty.*"

I had an opportunity to discuss this point in May, 1909, before the Iron and Steel Institute in London. On that occasion I pointed out that the design of the Kjellin furnace makes large capacities an impossibility, due to the great distance of the bath from the primary coils and the magnet. This is a drawback of the Kjellin furnace (and, of course, also a defect incident to the Roechling-Rodenhauser furnace) and this defect increases as such in proportion with the size of the furnace. Experience also proves that the power factor decreases quickly with increasing size of the Kjellin furnace. (I take the liberty to refer here to my construction mentioned in U. S. patent 980,259, March 1, 1911, where the body of the magnet is made hollow and can, therefore, be placed close to the bath and the copper coils, even if the diameter of the bath is increased to any desired degree.)

Mr. FitzGerald is certainly not aware of the fact that the designer of the Roechling-Rodenhauser furnace himself limits the capacity of his furnace as quoted above.

Further, when Mr. FitzGerald quotes a statement of Prof. Richards that I also use an electrode furnace for working up scrap, I beg to say that this information is wrong. I presume the statement referred to *one* of my induction-furnace patents. This patent covers a construction very much like the Roechling-Rodenhauser furnace, and refers to the use of auxiliary electrodes to which electrical energy is supplied from special coils around the magnet for additional heating of the slag-layer.

With respect to the latter point I refer to the two German patents 199,354 and 216,734 and especially to the first and third claims in the latter patent, the priority of which dates from May 5, 1906, while the patent first mentioned (Roechling's) is dated May 6, 1906. The difference between the two types of auxiliary secondary circuits is that Roechling passes his auxiliary secondary currents through the lining of the furnace and the molten steel, while I pass the auxiliary secondary currents through the slag layer for the purpose of heating it in this manner.

While mentioning this, I like to reply through your journal to a remark in Mr. Rodenhauser's "Electrische Oefen in der Eisenindustrie." On page 199 he says: "Hiorth has probably recognized in the mean time that this furnace construction is worthless."

This is not at all the case.

At the same time I wish to call attention to the way in which Messrs. Rodenhauser and Schoenawa describe my latest pure induction furnace in their book, where it is illustrated in Fig. 121 on page 200. In this illustration there is only shown a side-elevation of my furnace whereby in a high degree it resembles Kjellin's and other similar constructions, while not even an allusion is made to any drawing showing the principal features of my furnace, viz., *coiling of both legs of the magnet*, which was patented by me a long time before the Roechling-Rodenhauser furnaces were constructed.

In addition I may mention that in my furnace I need no blowing arrangement, the magnet as well as the upper coil being self-cooling and not insulated, and that with my construction the bath may be tilted independently of the magnet.

In view of all these facts and the further one that the construction, on account of its great simplicity and other advantages, is much cheaper than that of the Roechling-Rodenhauser furnace, I must admit that I am unable to understand Mr. FitzGerald's remark that the Roechling-Rodenhauser furnaces are superior in all respects to all other forms of induction furnaces.

On the contrary, I cannot see myself *any* advantage in the Roechling-Rodenhauser furnace in comparison with my furnaces, especially not for the large capacities here under consideration.

Kristiania, Norway. ALBERT HIORTH.

* * *

To the Editor of Metallurgical and Chemical Engineering:

Sir: It is not necessary that Mr. Hiorth should understand my remark "that the Röchling-Rodenhauser furnaces in all respects are superior to all other forms of induction furnaces" because I did not make such a remark. The notion I tried to convey was that so far as my experience went the Röchling-Rodenhauser was superior to other induction furnaces. No one would be better pleased than I, were Mr. Hiorth to construct a 30-ton furnace which was vastly superior to any other steel furnaces in existence. Several years' experience with electric furnaces, however, has convinced me of the folly of thinking any furnace that has not advanced beyond the paper stage superior to a furnace which is actually working successfully. Mr. Hiorth's letter does not produce any evidence that he has a furnace working that is superior to the Röchling-Rodenhauser apparatus.

As regards the quotation from Professor Richards' article: I had supposed this was authoritative, and it is to be regretted that Mr. Hiorth did not correct it at once when it appeared originally.

If I may take a little more of your space I would like to point out that ever since the electric steel furnace came into prominence its commercial development has been seriously hampered by the controversial methods of the numerous people engaged on various designs. This certainly has not tended to help any of the controversialists in making a money success of their various designs. A proper rivalry in such a case is a good thing, in that it stimulates the designer to try so to improve his furnace that it will have superiorities over those of his rivals. Thus, a Rodenhauser may try to make designs which will enable him to use the induction principle in large furnaces where refining can be carried on, for in that way he avoids the difficult problems of roofs and electrodes. A Héroult may improve a poly-electrode furnace so that the difficulties of the electrode are less than the objections to low power factor and high cost of construction. A Hiorth may make designs involving the induction principle which may greatly decrease construction cost and enable furnaces of much larger capacity to be used. But the rivalry which is chiefly busied in trying to show that another designer's furnace is bad: that the V furnace is a humbug and is never run except when prospective customers visit the plant; that the W furnace has a lining which comes up every time you make a heat; that the X furnace makes bad steel full of slag; that the Y furnace has absolutely no advantages over the Z furnace, is a rivalry which does no one any good, but simply makes the potential user highly suspicious of all electric furnaces. Then on top of all this we have the continual hurling of missiles in the shape of patents of more or less value, but certainly all tacked on to the original ideas of Siemens, Ferranti, and Colby.

Although I have never been in Missouri, when it comes to opinions on steel furnaces I am a psychological native of that state.

FRANCIS A. J. FITZGERALD.

FitzGerald and Bennie Laboratories,
Niagara Falls, N. Y.

Presentation of the Perkin Medal to Herman Frasch

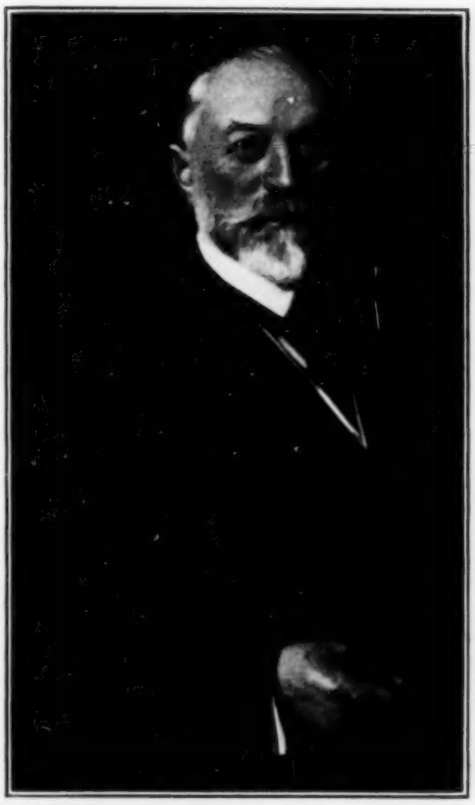
As noticed in our last issue, the Perkin Medal Committee (consisting of representatives of the Society of Chemical Industry, the American Chemical Society and the American Electrochemical Society) at its meeting of Dec. 15 awarded the Perkin medal for this year unanimously to Mr. Herman Frasch.

The formal presentation of the medal to Mr. Frasch was made at the meeting of the New York Section of the Society of Chemical Industry, held in the Chemists' Club in New York on Jan. 19.

The attendance was excellent. Rumford Hall and the balcony were well filled and the occasion was graced by the presence of many ladies.

The program was exceedingly well arranged and nicely balanced with the presentation speech of Dr. Chandler and Mr. Frasch's reply at the beginning, Captain Lucas' geological address at the end and in the midst the delightful intermezzo of Mr. Pough's moving picture exhibition.

The meeting was called to order by Prof. M. C. WHITAKER, who in a few, brief, graceful introductory remarks referred to the scope and importance of the Perkin medal and introduced the beloved dean of the chemical profession in America, Dr. C. F. Chandler, "who better than any other member of our profession can speak with knowledge and with admiration of the scientific achievements of our distinguished guest of this occasion, Mr. Herman Frasch." And Dr. Chandler did speak admirably.



From a painting by Hubert Vos.

HERMAN FRASCH.

Dr. Chandler's Presentation Speech.

Dr. Chandler began with a brief sketch of Mr. Frasch's early life:

"Herman Frasch was born in Gaildorf, in Wurtemberg, in 1852. In 1868 he took up the practice of pharmacy, came to America and was placed in charge of the laboratory of Professor Maisch at the Philadelphia College of Pharmacy. He found, however, that industrial chemistry interested him much more than pharmaceutical chemistry, and in 1874 he established a laboratory of his own. Here began the studies and investigations which resulted in some of the most important achievements ever accomplished in industrial chemistry.

"In 1876, at the age of twenty-four, he evolved a process for refining paraffin wax which was purchased by a Cleveland petroleum company affiliated with the Standard Oil Company. These companies were so well pleased with his first invention that they induced him to give up his work in Philadelphia, move to Cleveland and make the petroleum industry his specialty. He devoted himself assiduously to the refining of petroleum and made many improvements in the processes in use, for some of which he sought and obtained patents. The first was applied for Dec. 15, 1876, when he was but twenty-four years of age. It was for an improvement in apparatus and processes for the separation and treatment of oils by more completely separating the more volatile constituents from the less volatile, in order to increase the density, improve the fire test, sweeten the odor and otherwise improve the quality. This was followed by further applications for additional improvements for the same purpose. Five such patents were applied for between 1876 and 1885, all of which were granted.

"He also obtained a patent in 1884 for the manufacture of waxed paper, a material saturated with paraffin, which has found a great variety of applications. In 1885 Mr. Frasch invented an improved petroleum oil lamp.

"Our great inventor's attention was not, however, confined to petroleum. In 1882 he invented a process for manufacturing white lead directly from the galena ore. In the same year he devoted considerable attention to improving the processes and apparatus for manufacturing salt, a subject which continued to occupy his attention for several years. Five patents for his improvements in this industry were applied for in the years 1882 to 1899 and subsequently granted.

"He also studied the ammonia process for making carbonate of soda from salt, and between 1882 and 1886 applied for four patents for improvements, all of which were granted.

"In 1883 Mr. Frasch devised a very ingenious process of making elements for thermo-electric generators. In the same year he obtained two patents for the manufacture of a superior carbon for electric light carbons, and carbons for other purposes, from 'wax tailings,' or 'still wax,' by treating the same with nitric or sulphuric acid in a specially designed furnace.

DEODORIZING OIL.

"Mr. Frasch's contracts with the various oil companies expired in 1885, and he then moved to London, Ontario, where he went into business for himself, forming the Empire Oil Company. It was here that he solved the Canadian oil problem by devising a simple process by which the offensive oils of Canada and Ohio could be made so pure that they became as valuable as the Pennsylvania oil. There had never been any difficulty in treating Pennsylvania oil so as to obtain perfectly sweet gasoline, benzine, naphtha, burning oil, lubricating oil and paraffin for the simple reason that these oils were practically free from sulphur. But the Canadian and Ohio oils contained about 1 per cent of sulphur, in such offensive combinations that it was impossible to obtain from them, by the customary processes of treatment, products that could be marketed. So they were only available for fuel purposes.

"Many chemists attacked the problem of deodorizing those oils by decomposing the sulphur compounds; many processes were devised and patented, but not one of them was satisfactory until Mr. Frasch began to study the subject. On Feb. 1, 1887, he applied for his first patent for 'Refining Canadian and Similar Petroleum Oils,' and by Dec. 31, 1894, had applied for twenty patents for his inventions in con-

nection with this subject, all of which were granted. The essence of his invention consisted in distilling the different products of the fractional distillation of the crude oil with metallic oxides, especially oxide of copper, by which the sulphur was completely removed by entering into combination with the copper, while the oils distilled over as odorless and sweet as those from the best Pennsylvania oil. The process was comparatively inexpensive, as Frasch devised simple processes for separating the sulphide of copper from the residuum and restoring it by roasting to its original condition, making it possible to use it over and over again on fresh lots of oil.

"It was in the works of the Empire Oil Company that Mr. Frasch solved the problem of raising the terribly offensive sulphur-containing oils of Canada and Ohio from the low grade of fuel oils to the highest grade of purest oil. He had the process in operation on a large scale when, in May, 1888, the Standard Oil Company purchased his patents after they had been thoroughly investigated and tested by their experts. The company bought the works of the Empire Oil Company at London, Ontario, and proceeded at once to construct large works for carrying out Frasch's inventions at Lima, Cleveland, Whiting, Olean, Philadelphia and Bayonne. Mr. Frasch received in payment stock of the Standard Oil Company selling at that time for 168 and paying 7 per cent. After his process had been thoroughly established in the United States for Ohio oil he sold half his stock at 820, and the company had been paying for some time 40 per cent instead of 7 per cent.

"When one considers that the capital of the Standard Oil Company was $100,000,000, the pecuniary return from the Frasch process in the increased value of the stock and the magnitude of the greatly increased dividends assumes gigantic proportions.

"In addition to the advantages to the owners of the stock of the Standard Oil Company, there were a host of others who profited to an enormous extent. Frasch's process sent up the price of crude Ohio oil from 14 cents a barrel to $1 and above, thus benefiting the farmers and oil producers of Ohio, Indiana and Illinois, and also by greatly increasing the demand for this kind of oil until the production of this field went up to 90,000 barrels per day, giving an increase in return to the land and well owners of untold millions of dollars.

"Other inventions of Mr. Frasch in connection with petroleum refining are:

"In 1890 a process for removing from the heavier-burning fraction of the oil the sulphuric acid taken up during the acid treatment by the cracked products. This he accomplished by distillation with lime.

"In 1895 processes for increasing the flow of oil wells. The Pennsylvania oil wells occur in the Devonian sandstone, and in order to rejuvenate an exhausted well it had long been customary to shatter and crack the surrounding rock by exploding one or several hundred quarts of nitroglycerine at the bottom.

"In Ohio, Indiana and Illinois the wells occur at a much deeper geological horizon in the Silurian limestones. Frasch substituted sulphuric or hydrochloric acid in place of nitroglycerine for the purpose of rejuvenating the exhausted wells, one proving best in some localities, the other in other localities, as one yields insoluble calcium sulphate and the other soluble calcium chloride.

"By plugging the wells after the acid has been poured down the pressure of the carbonic acid gas forces the acid through the most minute cracks, which are thus widened so as to open communication with new cavities of supply.

"In 1900 the application of live steam to remove completely the gasoline, naphtha and benzine from the burning oil in the process of distillation in order to raise the fire test.

"In 1902 a process for treating the peculiar crude oil of Fresno County, California, so as to remove the valuable aromatic hydrocarbons which it contains: benzol, toluol, xylol, mesitylene and naphthalene.

"In 1902 a process by which it is made possible to secure a satisfactory burning oil from the peculiar crude oil of Beaumont, Jefferson County, Texas, which consists in washing out of the burning oil fraction its peculiar smoke-producing hydrocarbons, by means of wood alcohol.

"In 1899 improved processes to bring to the surface by solution the rock salt reached by boring.

"In 1894 a process for purifying solvent extracted oils, having a special reference to linseed oil, consisting in removing the solvent naphtha from the oil by low-tension steam in a partial vacuum.

"In 1895 improvements in mining gold or like metal, which consist in saturating strata containing the diffused metal with an aqueous solution of a suitable solvent, the final solution being subsequently drawn from wells or borings through the strata.

SULPHUR.

"On Oct. 23, 1890, Mr. Frasch applied for a patent for an epoch-making improvement in the sulphur industry. It had long been known that there was a large deposit of native sulphur in Calcasieu Parish, Louisiana, at a depth of 1000 ft. below the surface. But all attempts to get at the deposit and bring the sulphur to the surface had failed completely on account of the layers of quicksand above the deposit. Mr. Frasch evolved the idea of melting the sulphur in place by means of superheated water forced down a boring and forcing the melted sulphur through an inner tube. During the period beginning Oct. 23, 1890, to Feb. 6, 1905, Frasch has applied for ten patents for his inventions of apparatus and processes for accomplishing this result.

"His efforts have been entirely successful. The Union Sulphur Company was organized, he secured control of the sulphur deposit, set up the batteries of boilers, bored the wells, built the railroad to carry the sulphur to the seaboard and the docks at Sabine Pass for the ships which deliver the sulphur to the ports accessible from the various chemical works where the sulphur is used.

"There are seven batteries of boilers, each of which runs a well. A single well delivers about 450 tons of sulphur per day. In a two months' test six wells delivered 122,000 tons of sulphur, proving the capacity of the works to exceed the entire consumption of the world.

"The sulphur is pumped into bins constructed of planks about 50 ft. high, where it congeals and forms a block of from 75,000 to 150,000 tons, over 99 per cent pure sulphur. The planks are subsequently removed, the huge block is broken up by blasting and the sulphur is loaded directly into the cars by a scooping derrick which picks up two tons at a time.

"The effect of this work on the imports of sulphur into the United States is very far-reaching, as will be seen in the following figures, showing imports and exports of sulphur into and from the United States:

	Imports—tons.	Exports—tons.
1903	188,888	None
1907	20,399	35,000

"At present the Louisiana deposit supplies this country with sulphur and might supply large quantities to European countries. Fortunately the company is owned by a few broad-minded and large-hearted men, who could not be induced to bring starvation and ruin upon the two hundred and fifty thousand people dependent upon the mining of sulphur in Sicily.

"Ninety per cent of the stock of the Union Sulphur Company is owned by Herman Frasch, the estate of H. McK. Twombly, Abram H. Hewitt and Edward Cooper and Mr. L. H. Severance.

"I have presented to you very briefly the great achievements of Mr. Frasch in the field of applied chemistry; but quite fully enough to satisfy you that your committee is fully justified in placing Mr. Frasch by the side of Sir Henry

Perkin as one of our greatest industrial chemists and chemical engineers."

Turning to Mr. Frasch, Dr. Chandler concluded:

"It gives me great pleasure, as the representative of the Society of Chemical Industry and the affiliated chemical and electrochemical societies, to place in your hands, Mr. Frasch, this beautiful token of the appreciation and affection of your fellow-chemists."

Mr. Frasch's Reply.

Mr. Frasch expressed in a few happy words his thanks for the distinction conferred on him. He then presented an exceedingly interesting address on his work, which we print here in full. It contains much that will be new even to those familiar with the oil and sulphur industries:

OIL.

"Very little is known of the impurities contained in petroleum. They influence the price, however, to a remarkable degree. The best illustration of this is the case of Ohio oil.

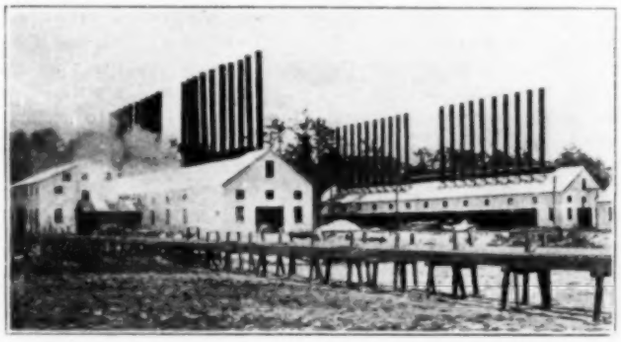


FIG. 1.—TWO OF THE SEVEN BATTERIES OF BOILERS ON THE PROPERTY OF THE UNION SULPHUR COMPANY, ONE EACH BEING USED TO PUMP A WELL.

This contains about 0.75 per cent of sulphur, and before my desulphurizing process was known sold at 14 cents per barrel, while Pennsylvania oil, with a sulphur content of only 0.03 per cent, sold at $2.25 at the same time. Sulphur affects the value of petroleum in a greater degree than phosphorus does that of iron ore.

"One of the oils which contains an objectionable amount of sulphur is that found near Petrolia, Ontario. It is the only crude that has been found in the Dominion of Canada. When this oil was first discovered in 1858 it was refined in the usual way—treated with sulphuric acid and soda and then put on the market. The result was disastrous. The odor emanating from the oil was very offensive and penetrating, so much so that the cargoes of ships carrying flour and bacon anchored near a vessel loaded with Canadian oil were spoiled, as the flour and bacon absorbed this odor. Lawsuits based upon these facts were decided against the shippers of Canadian oil and all export ceased. In order to protect the home industry, the Canadian Government imposed a duty of 9 cents per gallon on Pennsylvania oil, but in spite of this almost prohibitive duty half the oil consumed in Canada was imported from Pennsylvania.

"The offensive odor of this oil, moreover, was not its only objection. It had also the property of depositing soot upon the lamp chimney, so that a large percentage of the light emitted by the flame was lost.

"The Canadian Government, as well as the Canadian producers and refiners, made every effort to discover a method by which the objectionable properties of this crude oil could be eliminated, but practically nothing had been accomplished in twenty years, except perhaps in the matter of covering up the odor, when, in 1885, I bought a refinery in Canada and made a thorough investigation of the character of this crude and decided to discover a remedy, if possible.

"This dreadful odor, which the Canadians called 'skunk,' arose from a peculiar hydrocarbon sulphur compound, and the clouding of the lamp chimney was due to its sulphur contents. The sulphur in the oil burned into sulphuric acid, which condensed against the lamp chimney, and any unconsumed carbon or organic particles in the air would adhere thereto and form this objectionable soot. To remove the sulphur from the oil completely meant the elimination of the smoke as well as odor, and when this was effected the oil furnished an illuminant equal in quality to the best Pennsylvania.

"To free petroleum of elementary sulphur or hydrogen sulphide presents comparatively little difficulty, but the sulphur compound which is the cause of this offensive odor is very stable and cannot be broken up into hydrogen sulphide or any other sulphur compound which can be eliminated. It was because of the presence of this peculiar compound that Canadian oil for so many years resisted all the efforts made to refine it.

"This sulphur compound has the peculiarity of dissolving a number of metallic oxides. When the oil is saturated with all the oxide it can carry in solution the disagreeable odor disappears. It reappears, however, if any attempt is made to free the solution of its metal. I found that this solution of metal in petroleum has an intense affinity for sulphur, and also that, when a portion of the sulphur has been precipitated with the metal as a sulphide, additional quantities of metal oxide can go into solution. If more oxide than that necessary to precipitate all the sulphur is added to the petroleum while it is being distilled, a complete desulphurization of the petroleum is effected.

"When this petroleum solution is made with water-white petroleum distillate, which has been freed of elementary sul-

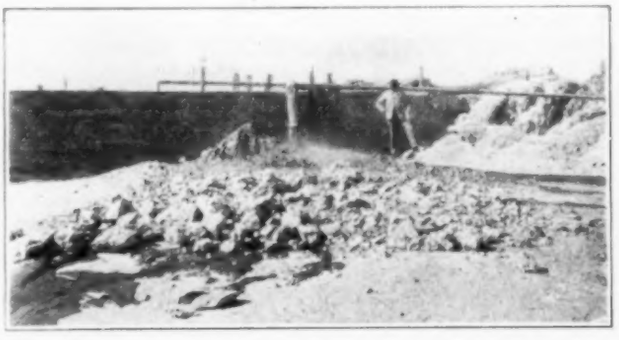


FIG. 2.—A WELL JUST STARTING TO PUMP SULPHUR.

phur and hydrogen sulphide, the solutions assume colors characteristic of each metal. The lead solution is a canary yellow, mercury orange, copper blood red, silver brown.

"I selected copper as the metal most suitable—first because it dissolves in the petroleum, and in the second place because of the readiness with which the sulphide of copper can be reconverted into oxide.

"When the laboratory work had been completed, I applied for letters patent and erected a 1200-barrel still, carrying on the process on a large scale. The shell of the still was 22 feet in diameter and 16 ft. high, and was supplied with a stirring device which kept the copper in suspension while distillation was carried on. After 80 per cent of the contents of the apparatus was distilled, the remainder, when cool, was pumped through a filter press. The solid portion was ignited and roasted, while the liquid residuum was mixed with a new charge of revivified oxide of copper to be used for the desulphurizing of a further quantity of sulphur-containing distillate. I used a shelf furnace, operated by hand, to roast the resulting sulphide of copper. In this manner I produced a burning oil containing 0.02 per cent sulphur, which is the percentage contained in Pennsylvania oil of similar specific gravity, while Canadian oil refined by the ordinary method has a sulphur content of 0.6 per cent.

OHIO OIL.

"It was about this time that oil almost identical with the Canadian was discovered in Ohio, and, while the question of refining Canadian oil was interesting, the problem became intensely important when 30,000 barrels per day were being produced in Ohio. The new field proved to be very extensive, and the Standard Oil Company bought property near Lima, Ohio, upon which they erected a large refinery. They disregarded the enormous difference in the sulphur contents of Pennsylvania and Ohio oils, decided to refine the latter in the usual way and put it on the market. When the refined product had been distributed among their customers, it all came back as unfit for use. Every effort was made to solve the difficult problem, but in 1887, after two years of experimentation and with all the skill which the Standard Oil Company could call to their assistance, it was decided that no illuminating oil could be made from Ohio crude and that it was fit only for fuel. A pipe line for this purpose was built to Chicago and long-term contracts made at 14 cents per barrel.

"My patents had now been granted and I was selling refined Canadian oil with a guarantee that it would burn equal to the best Pennsylvania. After an investigation which convinced them that I had solved this problem, the Standard Oil Company bought my patents and my refinery, and as soon as possible Lima, Cleveland, Whiting, Philadelphia and Bayonne were refining oil by the new method.

"The Ohio field was found to extend into Indiana and the production increased to 90,000 barrels per day. The price of this crude went up to nearly $1.00 per barrel, fluctuating between 60 cents and $1.00 for a great many years. The advantage resulting from the ability to use these oils for illuminants did not stop with the large profits of the Standard Oil Company, but the farmers and oil producers of Ohio and Indiana benefited by the enormous advance in the value of Ohio crude, which amounted to many millions of dollars per year.

METHODS OF DESULPHURIZATION.

"In desulphurizing petroleum, the oxide of copper is mixed with the petroleum distillate in a still supplied with an upright shaft and arms radiating therefrom, to keep the oxide in agitation during the process of distillation, flexible chains attached to the arms being used to prevent the copper from adhering to the bottom of the still. One hundred thousand pounds of oxide of copper is used for the first charge of 2000 barrels of distillate. After 80 per cent has been distilled off, a new charge of distillate is added with an additional charge of 30,000 lb. of copper, which is followed by two further runs, so that about 200,000 lb. of copper material is in the still when the fourth run is made. The residuum is pumped through a filter press, and the solid product of the filter press has the oil adhering thereto burned off. The dry mixture of oxide and sulphide of copper is then put into a roasting furnace, where it is desulphurized to 1 per cent or less.

"A variation of my method treats the vapor coming from a still charged with crude petroleum, and consists in passing the vapor through two brushes made of No. 10 steel wire, the brushes being 5½ ft. in diameter and 16 ft. long. They are inserted into a shell which is almost the same diameter as the brush, and the requisite amounts of copper and heavy oil are pumped into two shells, each containing one brush. The vapor passes, in series, first around the shell to prevent condensation; then through the shells on to the condenser. The brushes are made to revolve at about six revolutions per minute. These wires immersing continually in this oxide of copper magma, the shells containing the brushes are surrounded by the vapor coming from the still, and, as the temperatures of the vapors increase, anything condensed thereon during the prior period is re-evaporated by the hotter vapor following.

"Both these processes are now in operation at different works.

ROASTING FURNACE.

"When the question of supplying the copper necessary for the works at Lima was under discussion, it was found that 160 furnaces, such as I used in Canada, would be required to do the work. In order to avoid the handling and transportation involved in such a gigantic furnace plant, I was obliged to construct a mechanical roasting furnace of a capacity in conformity with the magnitude of the business.

"To eliminate the difficulties of the warping of the shaft and the arms which had caused the failure of the McDougal furnace, I constructed a stirring device, the shaft and arms of which were cooled artificially to withstand the high temperature of the roasting furnace. I first forced air as a cooling medium through the stirring device, but found that the oxidation of the sulphide of copper and the carbon from the residuum of the petroleum produced a temperature even higher than that of the ordinary pyrites furnace. It therefore became necessary to substitute hot water for air as a cooling medium, which proved very satisfactory. This made possible an increase in the size of the furnace to 16 ft. inside diameter, and to-day these shafts and arms are connected with stream drums and are used like a water tube boiler, so that the surplus heat extracted from the stirring device of the roasting furnace is converted into steam and utilized in the plant. The capacity of a furnace is 50 tons per day, and four to six are used in one refinery. After the copper has been revivified, it is ground and mixed with residual oil from the filter press. In this maner the copper charge is pumped into the still, which may be half a mile away. During the twenty years that this process has been in operation many millions of barrels of oil have been desulphurized.

CALIFORNIA.

"In 1902 the California field became important, and it was discovered that another oil which smoked chimneys had to be refined. This oil, however, was practically free from sulphur, the smoke being due to a large percentage of the aromatic series of hydrocarbons and to the fact that the percentage of hydrogen to carbon was too small to maintain the flame temperature necessary to consume all the carbon. I ascertained further that sulphuric anhydride converts the aromatic series into sulpho products, insoluble in petroleum, and that, by treating the distillates from the crude oil with sulphuric anhydride, the members of the aromatic series in the petroleum can readily be extracted.

"The existence of a petroleum containing nearly 50 per cent of the coal tar products is intensely interesting, especially in view of the theories advanced upon the origin of petroleum. The percentage of these hydrocarbons in the crude varies from the percentage contained in coal tar, benzol existing in a smaller proportion than toluol, while xylol represents 7 per cent of the volume of the crude. Napthaline, entirely free from all traces of carbolic odor, is quite prominent, while anthracene and carbolic acid are entirely absent.

"I employed numerous methods for separating the products of California crude by physical means. Distillation, with large back flow condensers attached, showed very encouraging results, as did also the method of washing the distillates with alcohol, carried on in series, the aromatic series being more soluble in alcohol than the paraffine series. However, the sulphuric anhydride treatment, which I first used in determining the amount of the two series contained in the petroleum, has proved to be very simple and effective on a large scale, and is now used by the Standard Oil Company at its plant in Port Richmond, Cal. The process of making the sulphuric anhydride employed there is the one purchased from the Verein Chemischer Fabriken, of Mannheim. The capacity of the plant has ben increased a number of times, until to-day it is by far the largest in the United States, if not in the world.

Sulphur

"In 1865, while boring for petroleum in Louisiana, a sulphur deposit was discovered beneath a layer of quicksand about 500 ft. thick. A result of this discovery, quarrels and con-

troversies arose as to whether the lease covering the petroleum rights also included the sulphur. It was some time before the matter was decided, and by the time a decision had been reached both parties had lost a great deal of money, and those who got the sulphur deposit lost still more in trying to exploit it. The deposit seemed to bring misfortune to every one connected with it, and I have heard many stories and met many people who told me of having lost money in the various schemes that marked the progress of the sulphur mine. Progress there seemed to mean failure. An Austrian company, a French company, and numerous American companies, everybody failed and not a ton of sulphur was produced.

"When I heard of this extraordinary situation, in 1891, I ob-

FIG. 3.—FILLING UP A BIN 50 FT. HIGH WITH SULPHUR.

tained a core from the sulphur deposit and many pamphlets from the various companies who had tried to operate it, each one telling the prospective purchaser that his fortune was made if he but owned a few shares of the stock of that particular company. I became interested, and, having had a great deal of experience in drilling and mining petroleum and salt, I thought the problem might be solved if all the facts concerning the deposit were known. Unfortunately, all the drilling records had been colored by the people who expected to float companies—everything unfavorable was concealed, and only that given which would be likely to induce investment, so that what I had considered a correct report proved later to be entirely wrong.

"Being misinformed as to the character of the deposit, I reached the conclusion that the sulphur was distributed in the rock, as in Sicily, and, when I heard of the limestone roof covering the deposit, I felt that sulphur could be found anywhere within reasonable proximity to the Sulphur Mines.

"To meet the extraordinary conditions existing in this deposit, I decided that the only way to mine this sulphur was to melt it in the ground and pump it to the surface in the form of a liquid. After careful study and consideration, I became convinced that this could be done. In view of the information obtained from the various companies, I believed that there was sulphur over miles of territory, and started to drill on land I had purchased within a mile and a half of Sulphur Mine. I went down over 2000 ft. without finding anything. Then I located a second, a third and a fourth well, but found no sulphur in any instance. This took much time and money, and I finally reached the conclusion that all the sulphur was located on the land owned by the New York company operating it at the time. They had a very ingenious scheme for sinking a shaft with a shield, but after the expenditure of a great deal of money the shield was lost, and the danger due to the presence of water containing hydrogen sulphide was demonstrated by the death of a number of men. It was decided to abandon this method, especially after a drilling record had been made by a drilling company who reported direct to the owners, when it was discovered that there was no roof over the sulphur, and that sulphur water was permeating the deposit in inexhaustible quantities.

"I realized at the outset that a method entirely different from that employed in the mines of Sicily was necessary for success here, as the class of labor required to operate this mine would demand at least $5.00 per day, while the Sicilian miners were being paid 60 cents.

"I succeeded in getting possession of the property, and at once set to work to drill a well of sufficient diameter to determine finally the character of the existing material. When this had been done, I was obliged to modify completely the process and apparatus I had expected to employ.

"At that time the drilling of a well in an alluvial deposit containing quicksand, etc., was a very tedious task, and it took from six to nine months to get through the alluvial material to the rock—work which we do to-day in three days.

SULPHUR PROCESS.

"I drilled a well through the alluvial deposit to the rock with a 10-in. pipe; then continued through the sulphur-deposit, which was about 200 ft. thick, with a 9-in. drill, and immersed a 6-in. pipe from the surface to the bottom in this well. The 6-in. pipe had a strainer only 6 in. long, at the very bottom and a seat to receive the 3-in. pipe through which we expected to lift the sulphur to the surface. The 6-in. pipe, directly above the seat for the 3-in. pipe, was also perforated for a distance of 3 ft.

"After the well had been drilled and before the pipes were inserted, it was filled up with sand in order to insure a tight receptacle at the bottom for the liquid sulphur. After the same

FIG. 4.—A MASS OF LOUISIANA SULPHUR READY FOR LOADING.

had been washed out, the pipes were inserted and equipped, and the well was ready for the melting fluid.

"This melting fluid consisted of water super-heated to 335° Fahr. The porosity of the rock in which the melting had to be done seemed to furnish an almost insurmountable obstacle to success, as I feared that the wild waters in the rock would break into the melting zone I expected to create and reduce the temperature of the fluid with which I expected to melt below the temperature necessary to fuse the sulphur. I had supplied a large number of boilers to furnish the heat necessary to maintain in the well a temperature higher than that required for the fusion of the sulphur.

"The water was superheated in columns in which 100 lb. per square inch pressure was maintained, and the apparatus which I had constructed to accomplish this proved efficient. We used twenty 150-hp boilers for a well, which represents experimentation on a ponderous scale.

"When everything was ready to make the first trial, which would demonstrate either success or failure, we raised steam in the boilers, and sent the superheated water into the ground without a hitch. If for one instant the high temperature re-

quired should drop below the melting point of sulphur, it would mean failure, consequently intense interest centered in this first attempt.

"After permitting the melting fluid to go into the ground for twenty-four hours, I decided that sufficient material must have been melted to produce some sulphur. The pumping engine was started on the sulphur line, and the increasing strain against the engine showed that work was being done. More and more slowly went the engine, more steam was supplied, until the man at the throttle sang out at the top of his voice, 'She's pumping.' A liquid appeared in the polished rod, and when I wiped it off with my finger I found my finger covered with sulphur. Within five minutes the receptacles under pressure were opened, and a beautiful stream of the golden fluid shot into the barrels we had ready to receive the product. After pumping for about fifteen minutes, the forty barrels we had supplied were seen to be inadequate. Quickly we threw up embankments and lined them with boards to receive the sulphur that was gushing forth and since that day no further attempt has been made to provide a vessel or a mold into which to put the sulphur.

"When the sun went down we stopped the pump to hold the liquid sulphur below until we could prepare to receive more in the morning. The material on the ground had to be removed, and willing hands helped to make a clean slate for the next day. When everything had been finished, the sulphur all piled up in one heap, and the men had departed, I enjoyed all by myself this demonstration of success. I mounted the sulphur pile and seated myself on the very top. It pleased me to hear the slight noise caused by the contraction of the warm sulphur, which was like a greeting from below—proof that my object had been accomplished. Many days and many years intervened before financial success was assured, but the first step toward the ultimate goal had been achieved. We had melted the mineral in the ground and brought it to the surface as a liquid. We had demonstrated that it could be done.

"This was especially gratifying, as the criticisms I had received from technical papers and people who had heard of what I was attempting to do had been very adverse. Every one who expressed an opinion seemed to be convinced that this thing could not be done, one prominent man offering to eat every ounce of sulphur I ever pumped. A fair illustration of public opinion is the remark of the mail boy who drove me to the railroad the morning after our first pumping. He said: 'Well, you pumped sulphur sure, but nobody believed it but the old carpenter, and they say he's half crazy.'

"This severe criticism, while not agreeable, did not carry very much weight with me. I felt that I had given the subject more thought than my critics, and I went about my work as best I could, thoroughly convinced that he who laughs last laughs best.

"At first we pumped with an ordinary deep well oil pump, changed to meet the corrosive action of the sulphur. We experienced great difficulty with the valves in the pump, the high specific gravity of the sulphur, the great depth from which it had to be raised and the corrosive action of the mineral itself making the maintenance of valves very difficult. Zinc and aluminium are practically the only two metals unaffected by liquid sulphur, but both these, being soft and easily disintegrated, would not withstand the shock at the change of stroke of the pump. I decided that, if the specific gravity of the sulphur could be raised by the admixture of some other body much lighter, a point might be reached where the hydrostatic pressure of the water in the ground would raise the sulphur. Air seemed the most suitable, and we introduced compressed air into the column of liquid sulphur standing in the well, using a volume of two parts of air and one of sulphur. We have raised our sulphur discharge lines 70 ft. above the ground, so that we can fill bins to a height of 65 ft. without machinery or pump of any kind in the sulphur proper.

"The first well lasted long enough to demonstrate the possibility of success, and to indicate in what directions improvement must be made. At that time my sulphur enterprise was merely a hobby, the bulk of my time being devoted to my Standard Oil work.

"Many difficulties arose which we had not foreseen. We lost some wells because of the parting of the pipes. As the mineral was melted from the bottom, the earth above would follow as the sulphur rock settled. The grip of the sand and earth against the pipe was so great that, instead of sliding, it would pull the pipe in two and the well would be lost. A 12-in. pipe outside of the 10-in., with stuffing box and telescope joints, obviated this difficulty. All wells, however, are eventually broken and crushed, when the abstraction of sulphur becomes so great that the cavity made cannot withstand the weight of the ground above it.

"We succeeded in increasing the life of a well greatly by lining the hole drilled through the rock with a 9-in. perforated pipe.

"About that time we found that some wells gave out and ceased to pump when there had been no breaking of the pipes. I reached the conclusion that the cold sulphur water permeating the rock had broken into the melting zone, and brought the temperature of the melting water below the melting point of sulphur. I thought this might be remedied by pumping large amounts of a material like sawdust into the mine with the melting fluid, and that if the quantities of sawdust were large enough, the channels through which the wild waters in the rock entered the melting zone could be sealed.

"One well, after pumping about 7000 tons, at the rate of approximately 350 tons per day, ceased to produce. The pipes were all in good order, and we started to pump sawdust into the ground with the melting water. After pumping in about six carloads per day for five days, the well 'sealed' with sulphur and promptly produced 39,000 tons more before the caving of the rock broke the pipes.

"We perfected this method of artificially 'sealing' the rock surrounding a melting zone, so that the amount now obtained from a well has been greatly increased. Whenever a well breaks we shoot off with dynamite the 10-in. pipe in the quicksand above the rock, and permit the sand to follow into the cavity from which the sulphur has been abstracted, filling up the space of the extracted sulphur rock with sand. The surface, consisting of about 200 ft. of clay, follows the quicksand, gently but surely, and in order to maintain the pressure which is necessary to prevent the melting water from breaking into steam, the volume of the sulphur abstracted from below must be replaced by earth from above. To do this a dredge with a capacity of 4000 cu. yd. per day became necessary. Numerous reservoirs have been dug on the outskirts of the mine to supply the material required to do this. This filling has been going on constantly, and the ground has sunk to such an extent that where our house once stood is now 80 ft. below the original surface.

"These improvements were made slowly, as all experiments had to be made on a ponderous scale, and the smallest change required a great deal of time. During the long intervals which necessarily elapsed between my visits to the mine I could give this new enterprise no attention. It took months to drill a new well when an old one was lost. At one time the work lay idle for a whole year before I could take it up again, and it was not until 1903 that we could see financial success ahead. In that year we produced 35,000 tons, and in 1904 enough to supply the entire consumption of the United States. It was in that year that we sent the first cargo of American sulphur to France.

"In order to demonstrate what the mine could do with six wells, we pumped that number simultaneously for six months, producing 122,000 tons of sulphur, which is more than the consumption of the whole world for that period of time.

"Prior to the development of the Louisiana sulphur mine, the sulphur production of the United States was less than one-half of one per cent. of its consumption, practically the entire amount required being supplied by Sicily and Japan. The former really had a monopoly of the sulphur business for a great many years.

The Sicilian sulphur industry was closely interwoven with the Politics of the islands, both internal and external. It was in 1833 that an English fleet appeared in the Bay of Naples to compel the Italians to rescind the sulphur monopoly that had been granted to France.

"The ups and downs of the Sicilian sulphur business are extraordinary. The people, a large percentage of whom are employed in the mines, are very poor and used to be in the hands of dealers and usurers, who manipulated the sulphur market to suit themselves, and extremely high prices and extremely low prices followed each other, as suited their convenience.

"In England a process had been discovered for the recovery of sulphur from the waste products of the Leblanc soda process, quite a large amount of money being invested in the necessary machinery. When another sulphur crisis occurred in Sicily in 1894-5, and sulphur sold below the cost of production of English recovered sulphur, a number of English capitalists decided to finance and market the Sicilian output. They incorporated as the Anglo-Sicilian Sulphur Company, and succeeded in getting between 75 and 85 per cent. of the Sicilian mine owners under contract for the entire output of their mines, whatever that might be, at a fixed price. This arrangement was made with the consent of the Italian Government for a term of five years, with the privilege of renewal for five years more. The scheme proved an excellent one, both for the Anglo-Sicilian Company and for the Sicilians. The former made a great deal of money, paying about 50 per cent. per annum on their common stock, and reserved large sums for contingencies. The contingencies arose in the form of the Louisiana sulphur production, which came like a bolt out of a clear sky. They had received complaints from their agents here that the business in the West had diminished on account of sulphur furnished from a mine that was no mine at all, but where the sulphur came out of the ground ready to ship. The Anglo Company, as well as the Sicilians, declared that this was impossible, and that the whole thing was an American swindle.

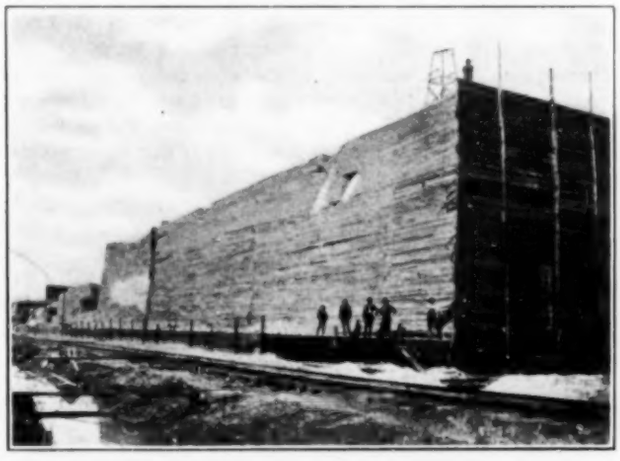


FIG. 5.—MASS OF LOUISIANA SULPHUR, 48 FT. HIGH, SHOWING THE SIDE TOWARD THE TRACK WITH THE BOARDS REMOVED AND THE END WITH THE BOARDS INTACT.

"I was very anxious to get all the business possible, as our stock pile was much larger than our bank account, and I was surprised to hear that the Anglo-Sicilian Company had accepted a contract for 20,000 tons to be delivered in America, very much below the price they generally quoted, and not far above their cost. I decided to go to London and have a talk with them in order to find out if it would be necessary for us to put the price below their cost in order to maintain the American business, which we needed very badly. I was perfectly frank and explained our position fully. I met with a great lack of enthusiasm for this 'American humbug,' and was told that they would go their own way, and I could go mine. I did. I had arranged for the sale of our sulphur in the various European countries, and knowing the production cost to my competitors, I succeeded very shortly in demonstrating that Louisiana sulphur was not a swindle. I found out afterwards that the lesson had cost the Anglo-Sicilian Company 285,000 pounds sterling—but then we were friends. Their attitude changed greatly, and they decided to go out of business and let the Sicilians and Americans take care of themselves.

AN OBLIGATORY TRUST.

"The Anglo-Sicilian Company, especially during the last years of its life, had found it necessary to store a great deal of the sulphur tendered to them on their contracts, as they had lost the American market, which was their best customer, and it looked very much as though this enormous accumulation, approximating 500,000 tons, would have to be thrown on the market to be sold for whatever it would bring. To the poor Sicilian miner, whose lot under the most favorable circumstances is not an enviable one, this would have meant sulphur below cost, with the eventual closing of the Sicilian mines and misery and starvation to a large population.

"The men well acquainted with the situation felt, as I did also, that this would result in revolution and bloodshed for Sicily. The laborers could not live on a wage lower than that which they already received. Frequent strikes and disturbances occurred when the misery of the working people was greater than usual.

"Understanding the peculiar character of the Sicilians, the Government, when the matter was brought to their attention, decided to form an obligatory trust, so that no sulphur would be sold below cost, and the Government was to finance the large stock on hand by issuing bonds and guaranteeing the interest. All the Sicilian sulphur mines were to be included in this obligatory trust, and the Government agreed to advance, in cash, four-fifths of the value of the sulphur when it was received from the mine owners, the remainder to be paid to them after payment for the sulphur sold had been received and the expenses of conducting the business deducted.

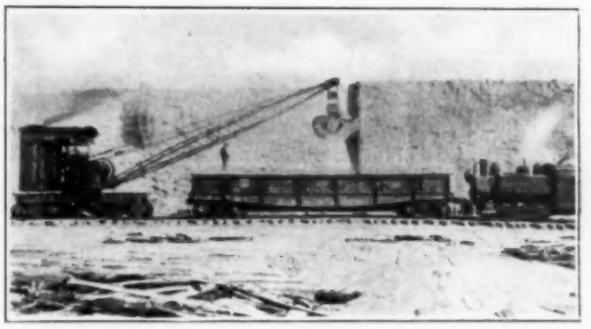


FIG. 6.—LOCOMOTIVE DERRICK LOADING A CAR WITH 25 TONS OF SULPHUR IN 14 MINUTES.

"A law creating this obligatory trust, which is known as the 'Consorzio Obbigatorio per l'Lindustria Solfifera Siciliana,' was passed, and it has been in operation since August 1, 1906. It has gone through the vicissitudes of childhood and occupies a unique position among the various trusts, which is of special interest to the United States. Here we have in successful operation a trust created by force which all those engaged in that particular business are obliged to join. It has a board of thirty directors, an executive committee of ten, four of whom are members of the government, and a Royal Commission, also appointed by the government, who is practically its president. Prices are fixed and maintained, and sulphur is sold to all comers at the same figure.

"This obligatory trust has been a godsend to the people, and so well are the Sicilians satisfied with its operation, that they have already petitioned the Government to extend the period of its life beyond that originally decided upon. Moreover, the

present Commissioner's able and wise administration has been so successful that the Sicilian stock of sulphur on hand, the obligation of the Consorzio toward the Government and the Bank of Sicily have been diminished to such an extent that the stock will be reduced to normal within two years and the Consorzio will be entirely out of debt. It is a striking illustration of the fact that a trust may be beneficial to all concerned. Great credit is due to the Italian Government for averting the misery which would inevitably have followed another sulphur crisis."

Moving Pictures.

Mr. Francis H. Pough followed with a brief but very interesting account of the works of the Union Sulphur Company, illustrated by numerous lantern slides, a few of which are reproduced in the adjoining illustrations. This was followed by an exhibition of moving pictures on the screen, giving a very vivid and direct idea of the enormous scope of the Louisiana works of the Union Sulphur Company, of the methods of working, the sanitary conditions of the workmen's houses, etc. In fact, in fifteen minutes the audience could learn practically as much as by walking over the mines for a day. Moreover, the information thus pleasantly presented was absolutely up-to-date, since the film photographs had been taken only a week ago. An exhibition of these moving pictures at some session of the coming International Congress of Applied Chemistry would certainly prove a very attractive and instructive feature.

Geology of Calcasieu Sulphur Mines and Sulphur Oil Fields of the Coastal Plain.

The concluding address of the evening was made by Captain Anthony Francis Lucas, of Washington, D. C., on the geology of the great Calcasieu sulphur mines and the sulphur oil fields of the Coastal Plain. In his impressive, instructive and interesting paper Captain Lucas proposed to touch the subject only by some practical observations, which through the success of Mr. Frasch have become of international importance, and which make me feel glad to be an American citizen.

"America stands abroad as a great country, and Americans as great men who do great things, men who, undaunted by failures of others, have undertaken and carried to practical solution problems that appeared foolhardy to undertake, and the success of this accomplishment must in all candor be ascribed to genius, especially so when this genius compels other nations to take notice and 'willy-nilly' pay him tribute.

"The geology of the coastal plain—which, of course, includes the Mounds or Domes—extends over a vast area, practically beginning at the northwestern coast of Florida for about 50 to 100 miles in width, and following the littoral zone of the Gulf States of Alabama, Mississippi, Louisiana and Texas down to Mexico and beyond.

"This vast area is practically as level as a floor, with a slight dip toward the sea, and in traveling westward one comes upon slight elevations of, say, from 10 to 100 feet in height over the surrounding prairie. These elevations, which we will later on feel warranted in calling Domes, are of limited area, say, from 250 to 2,000 acres, which have by now assumed wonderful economic importance.

"It is, therefore, precisely of these elevations that we will speak, for they now form the basis of the whole economic geology of the coastal plain in the States of Louisiana, Texas and the Gulf States of Mexico.

"To attempt to make soundings in search of minerals of economic value beyond this elevated zone is perfectly useless, as the drill will only encounter the clays, sands and gravel of the Pleistocene Columbia series, then the red sands of the Neocene Lafayette series, and deeper down the blue clays, Gumbo and sporadic laminations of limestone, at which time the driller (if he is lucky to have reached this depth safely) will be glad to pull out and call it done.

"It is true, however, that at time these elevations are so slight that the 'wild catter' often confuses them with the local phenomena of the ant mounds and feels warranted to drill anyway, and we have instances on record where he eventually hit the apex of a hidden dome, as it happened, for instance, at Batson Prairie, Texas, whereby he obtained economic results.

"Undoubtedly there are more such hidden domes scattered over this vast area, and I make a passing reference to the possibility of their existence in order to point out the hazard of hitting any as very great.

"We will now proceed from New Orleans westward, and come upon "Belle Isle," the first of a series known as the five Salt Islands.

"These islands are of limited area, or from 250 to 1200 acres in extent and rise abruptly out of the surrounding marshes at an elevation of from 60 to 200 feet. They have all been explored and salt found thereon except 'Cote Blanche.' . . .

"The salt of all these domes is of remarkable purity (98 to 99 per cent. sodium chloride) except perhaps at Belle Isle, where part of this salt mass is saturated with petroleum. Following the contour of this dome by drilling near the apex, and while sinking a shaft the occurrent of galena and sphalerite was ascertained. The crystals are all sharp, and show no sign of erosion. Dr. A. C. Gill, of Cornell University, states that the galena shows no silver and the probability is that it represents a deposition from salt water by chemical action.

"The borings made at Belle Isle for oil and sulphur have disclosed lenses of considerable limestone and sulphur, and pools of water escaping from some wells are strongly charged with H_2S and SO_2, and yet the oil recovered from these wells gives no indication of containing sulphur in any form. This oil is parafine base, of 45 degrees Beaume, and has the appearance of being like Pennsylvania crude, only somewhat lighter in color still. Upon submitting a sample of this oil to the Standard Oil Company officials it was difficult to convince them that this oil had not already been refined in whole or in part.

Further explorations on this island have been suspended, as it was found unpractical to work the same for oil or salt. Grand Cote and Petite Anse are now producing a superior quality of rock salt, most of which is shipped to the Northwest in competition with the Michigan and New York salt.

"Anse La Butte, six miles north of Lafayette, is also a salt dome of limited area, which, however, has so far produced a few good oil wells. The oil carries some sulphur and is of 21 degrees Beaume, and is used principally for fuel.

"The Jennings field, on which oil was found at 1800 feet in considerable quantities, is also a dome, but so far no salt has been found thereon. It is believed by Professor G. D. Harris, of Cornell University, who for years has carried on most thorough and indefatigable work on the coastal plain of Texas and Louisiana that larger oil resources lie beyond the limit of the proven field.

"Of smaller importance is the field of Welsh, which is producing, however, an excellent grade of oil, but so far no salt-rock has been found, and the wells as a rule yield the best result at about one thousand (1,000) feet. This field gives no indication on the surface of primary or secondary doming.

"The oozing of petroleum and escape of gas at Bayou Choupique, now known as the sulphur mines, led the Louisiana Oil Company to drill for oil in 1868, and after going through the clays and sands of the Pleistocene, the quicksands and gravels of the Columbia to 443 feet, entered a gray massive limestone of about 60 feet in thickness. Under this, almost pure alternate layers of sulphur and limestone were found for a thickness of about 260 feet; below this lie the gypsum beds, with occasional layers of pure sulphur. It remains to be proved by deeper drilling if this dome is also underlayed by rock salt. The geological age of this dome has been ascribed by Hilgard as cretaceous, by Harris as eocene. The fossils, as classified by Ban Ingen, are of tertiary, and by Dall and Aldrich, of miocene origin.

"A new company was organized by General Jules Brody to win this sulphur by sinking an iron ringed shaft, and after

reaching a depth of one hundred and ten (110) feet the shaft was abandoned on account of a break in the lining and the asphyxiating of several miners by sulphur gas."

Captain Lucas then gave an account of Mr. Frasch's work and successful solution of the problem, which has already been fully covered in the preceding pages. Captain Lucas continued:

"Since the advent of the sulphur, no serious attempt has been made to explore the sources of heavy oil that still flows from the upper layers of some old test wells, except by the Beaumont boomers in 1901, and I am of the opinion that if Mr. Frasch was to make a serious attempt he would succeed, not only to get the oil in gushers, but also little Chinamen with firecrackers from the lower regions.

"Numerous attempts have been made to explore the 'Vinton Dome, about fifteen miles west of 'Sulphur,' but progress was impeded principally owing to the heavy gravel and quicksand beds of the Columbia, until about one year ago the many

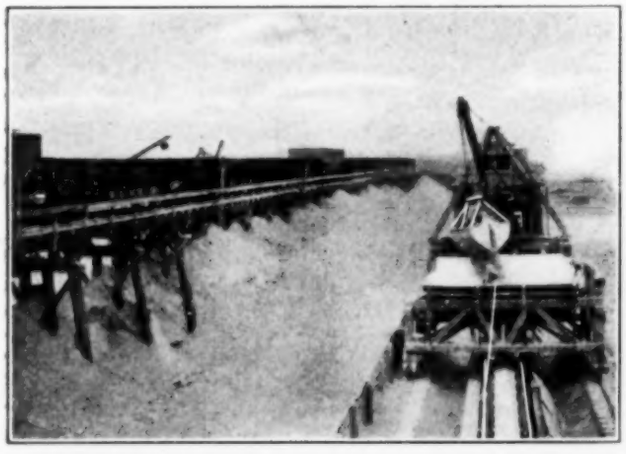


FIG. 7.—LOADING SHIPS WITH SULPHUR AT SABINE, TEXAS. CLAM-SHELL DREDGES DELIVER SULPHUR ON TO BELTS WHICH CARRY IT INTO THE SHIP.

efforts have been crowned with success. The Vinton field now furnishes considerable oil of about 21 degrees B., which carries about half per cent. sulphur.

"You have all heard from the fields of 'Spindle Top,' 'Sour Lake,' 'Saratoga,' 'Humble,' etc. They are also salt domes, and have produced great quantities of sulphur oil of an average specific gravity of 22 degrees Beaume, and Spindle Top alone is credited with about forty-three million barrels of oil to date.

"On Spindle Top was made the first discovery of sulphur oil of the coastal plain on January 10, 1901. It is also a salt dome and lies at an elevation of only 12 feet from the surrounding prairie, the surface of which contains about 235 acres only. Explorations had been made in 1882, 1885 and 1888 in search of sulphur or oil, but owing to alternating beds of quicksand and gravel of the Columbia, it was found impossible to go deeper than 300 feet, until in October, 1900, I made the second attempt, and after going through irregular alternating beds of clays, sand, gravel, lime, calcite and sulphur, reached the oil rock at 1120 feet depth. The pressure of gas and oil was so great that the four-inch drill pipe was shot out to a great height, carrying the head block, swivel and cable with it. Then a great rush of mud and water came out (the water used for drilling) followed by the ejection of large fragments of dolomite and fossils. It settled then to a steady flow of oil to a height of about 200 feet through a six-inch pipe. The well flowed continuously for ten days, when it was finally closed by an eight-inch gate valve. This oil was heavily saturated with H_2S and SO_2 and was very offensive to the nose, while the well was in eruption, as within a radius of several miles all houses painted with white lead were blackened, also the silver in houses, and even to the silver coins in circulation. It was estimated that this well flowed in ten days while in eruption about 750,000 barrels of oil. The oil rock is a porous dolomite carrying some sulphur in crystals and containing considerable calcium over magnesium.

"The size of the cavities into the dolomite can only be estimated by the large fragments shot out from the wells while in eruption. Drillers, however, reported instances of their tools dropping for several feet, leading one to conclude that the oil rock is cavernous, which in consequence made an admirable storage reservoir for the oil. The actual thickness of the oil-bearing rock is undetermined, but it has been estimated to be from 75 to 150 feet thick. A test well drilled near the discovery well entered gypsum at about 1200 feet and at 1650 feet encountered rock salt, which continued to a depth of 1900 feet, when the drilling stopped.

"The discovery of this oil pool started a celebrated boom in Texas and Louisiana. Many men and women with speculative oil tendencies were stirred up from Mexico to the Appalachians, with Spindle Top as an objective centre. The mere fact of land being in the vicinity of Beaumont sold it at fabulous prices, while fractions of an acre on Spindle Top sold at the rate of $760,000 per acre. Not that there was any value thereon warranting such prices, but that it enabled the boomer to capitalize his twenty-five by thirty feet of land, near a known gusher, at millions of dollars. However, by the time he was through with the sale of his stock, widely advertised, a well

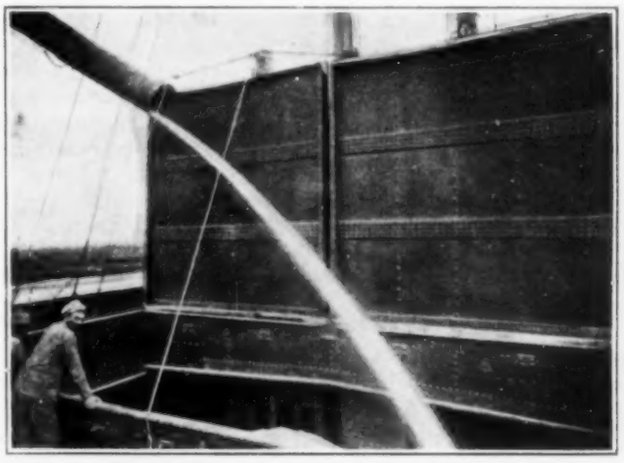


FIG. 8.—S. S. MELROSE RECEIVING LOUISIANA SULPHUR BY MACHINERY AT THE RATE OF OVER 10 TONS PER MINUTE AT THE UNION SULPHUR COMPANY'S DOCKS IN SABINE, TEXAS.

came in dry and the boom collapsed, and so did most of the many hundreds of companies capitalized at enormous figures. Had Spindle Top been sanely exploited by experienced drillers, I am confident that it would gush to-day.

"Still traveling westward we come upon other domes, such as 'Hoskins,' 'Bryan Heights,' 'Big Hill in Matagorda' and 'Big Hill in Jefferson County,' 'Damon,' 'Kyser,' 'High Island,' 'Barber Hill,' etc., all of which have been explored, but so far have been found barren in whole or in part.

"High Island and Damon Mound, two interesting elevations of 50 to 100 feet above the surrounding prairies, and of about 3,000 acres in extent each, have practically the same characteristic indications that Spindle Top had, to-wit: The elevation above the prairie indicating a possible dome, the sour water, the springs charged with the hydrogen sulphide, the gas escape, etc. The opening of a well, drilled by hand at High Island in search of water, was plugged with straw, and a few years later the plug was extracted and found to be a solid mass of sulphur; yet after repeated drilling to a considerable depth on this Island and Damon Mound, nothing of commercial importance was found. The drill passed through alternate beds of quicksand, silicious clay, sulphur and clay, some oil and salt at bottom.

"At Big Hill, Jefferson County, Texas, also an attractive possibility for an oil proposition, solid dolomite was found at 350 feet, which continued to a depth of 1400 feet.

"At Bryan Height a great gas pressure was encountered in 1901 charged with hydrogen sulphide, but it was subsequently abandoned. Big Hill, Matagorda County, had a small production. The oil was found at depths of 885 to 1050 feet, in limestone which possesses the same characteristic features of the oil-bearing rock of Spindle Top. As much as 60 feet of solid sulphur was reported from some wells, and always near the oil horizon. The oil was proportionately charged with it, and the gas, chiefly H_2S mixed with SO_2.

"In conclusion I would say that the Domes of the Coastal Plain have broken the world's precedents. First, for the limited area, second, for the productiveness as yet developed, and this holds good for sulphur, oil and rock salt, which goes to the credit of the Coastal Plain only.

"There are other richly productive fields of somewhat older geology, but want of time precludes me from describing them.

"By glancing at the map you will note that the Southern Pacific Railroad found itself to be located on to every field as fast as discovered, and I was told by a 'wag' that when the Almighty created the Universe He also located this railroad, and at once got busy to provide material for this road to haul, and that is the reason why He placed the sulphur deposit and oil pools and the rock salt adjacent to its line. This road was the first one to utilize this cheap and convenient resource as fuel and this at a minimum cost.

"He then improved and grew magnificent forests of timber also adjacent to this line, and then prepared the soil for the unexcelled culture of rice and sugar.

"The whole of these enormous commercial resources were placed by Him, so to speak, in the front yard of this fortunate railroad, and without the expenditure of a dollar for their advertising bureau, so that I feel justified in concluding to call the foregoing the Economic Geology of the Southern Pacific Railroad."

After the formal conclusion of the meeting many of those present remained together informally examining Mr. Pough's sample exhibits, while Mr. Frasch was kept busy in shaking hands with his many admirers. Altogether it was a most enjoyable evening.

Hardness of Plasters and Cements, and a Simple Chronographic Apparatus for Recording Set*

By Dr. Chas. F. McKenna.

One cannot give a clear definition of the term "Hardness" which shall serve for all the meanings in which it is used. The mineralogist using Moh's scale always means by this a measure of resistance to scratching or abrading; the wood-worker means the resistance to cutting; the steel-maker sometimes means by it the resistance to deformation under applied loads; in fact, indentation tests rule in many fields rather than scratching, cutting, or any other form of test.

In the case of hydraulic cements, the first stages of hardening have been usually measured by resistance to penetration; the later stages by finding the increase of cohesion determined by resistance on uniform cross-section to tractive or compressive forces gradually applied until rupture occurs.

The *setting* of plasters and cements is the very first stiffening and rapid development of cohesion up to the stage where needle-points under moderate pressures do not penetrate the surface, or where small test objects are easily handled without fracture. Beyond this the phenomenon, in which the cohesion due to complex mineral-forming reactions is step by step increased until a considerable age is reached, is called the *hardening*.

*A paper presented at the Washington meeting of the American Institute of Chemical Engineers on Dec. 21, 1911.

The chemical phenomena occurring in the setting of plaster of paris are chiefly those due to the energy in supersaturated solutions. Where a small proportion of water is used a hydrated sulphate of lime of one form goes into solution and the concentration causes the settling out or solidification of another form of hydrated sulphate; the water released from this helps to dissolve more of the first form, which, by concentration, duly deposits again, and thus the process is continuous to total solidification. Similar phenomena can be observed in supersaturated solutions of some salts, which can be caused to deposit crystals and thicken almost to total solidification. The setting of such a compound of hydrated sulphate of lime is rapid, and except for effects of drying, the maximum hardness is obtained a very few hours after the gauging.

FIG. 1.—GILMORE APPARATUS

In the setting of hydraulic cements we have something much more complex, though we have been instructed by the case of plaster and by some of the points of similarity in it.

Powdered Portland cement clinker is a complex solid solution of silicates and aluminates rich in lime. When it is wet the alkaline lime solution resulting reacts on the silicates, producing a colloidal mass. A thermal effect occurring here in the beginning is the absorption of heat due to solution or the passing of the solid salts into the ionic condition.

In the setting of cement the first gelatinous mass formed is less and less permeable, due to drawing away of water coincident with the lowering of temperature; then as the crystal formation begins, the proportion of free water momentarily increases again and softens the colloids. Later the full interlacing of crystals and the drying of the colloids admit less and less of penetration, and thus we have the development and finally the end of the process of setting.

FIG. 2.—VICAT NEEDLE

Hardening can then go on through further molecular interchanges leading up to the formation of silicates of lime and alumina analogous to some of the hydrous silicates of mineralogy.

According to Michaelis the exact steps are described as practically a migration of water throughout the mass. The first particles of clinker are dissolved on the surface, the supersaturated lime solution thus formed reacts to form a gelatinous mass, and when crystals of aluminate of lime are formed the water separated goes further to attack newer particles of the clinker nodule, later deserting the colloids formed and passing into the air or into the water in which it is immersed.

These reactions are complicated again by the presence of sulphate of lime, which serves to form with the aluminates of lime a double compound of slow setting qualities, neutralizing the usual effect of a cement rich in aluminates of lime, where the setting is very quick and the development of heat sudden and great. Thus you will observe we consider setting to be consequential upon the formation of both colloids and crystaloids.

Apparatus for observing these changes in the setting process have usually been simple. For expert workers it suffices to use the thumb-nail. With skill and accustomed observation they thus obtain a definition which is as remarkable as the means are simple. Nothing has been developed toward providing means for observing set in plaster of paris: the contraction and dilatation, however, have been observed by Vant Hoff in a beautifully simple apparatus.*

General Gilmore recommended, for observing set in Portland cement, a weighted coarse wire and a more heavily weighted fine wire (Fig. 1) for the determination, respectively, of the first stiffening (initial set), and the firm resistance to any penetration or deformation (final set). Neither of these methods is instrumental or fitted to record distinct differences.

The first apparatus designed for such a purpose was that of Vicat, the French chemist and authority on cements. The Vicat needle (Fig. 2), is a weighted one, cylindrical and 1 square millimeter in area on the face, moving in a vertical scaled-off guide and falling upon the mass of gauged cement in a mould below. The initial set is taken as the time at which the needle will not penetrate within a certain distance of the bottom of the mass, and final set as the time when there will be no mark upon the surface from the needle.

However, chronographic and automatic apparatus have been sought for.

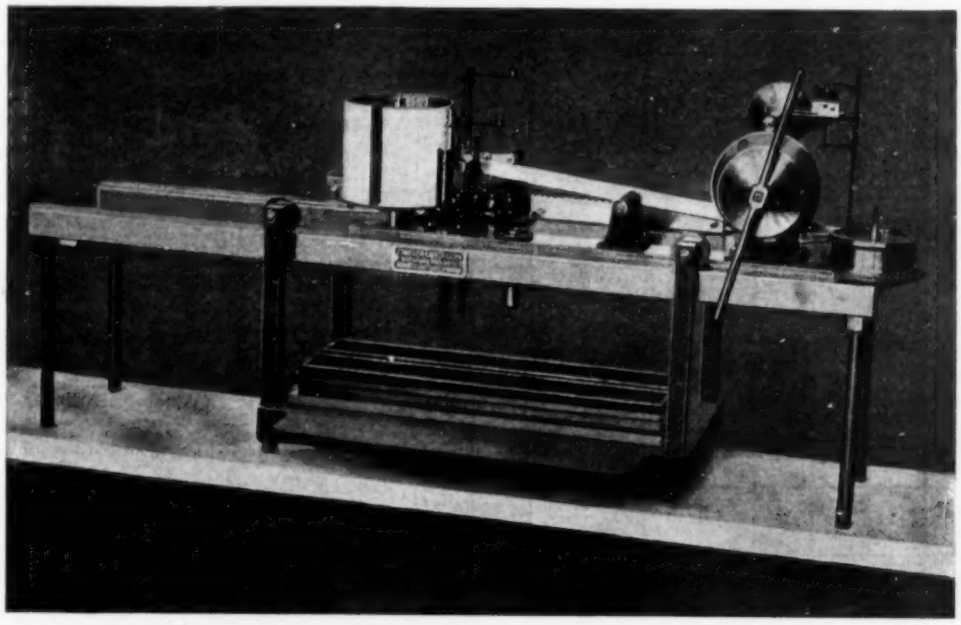


FIG. 3.—AMSLER-LAFFON CEMENT SETTING RECORDER

Professor A. Martens, of Charlottenburg, designed an apparatus in which needles energized by magnets are dropped and raised again as a clock movement makes the contacts.

The Amsler-Laffon cement setting recorder, Fig. 3, has been used in Europe. This is described in the journal *Cement*, from which the accompanying cut it taken, and the following description: In testing the activity of cements by this apparatus two moulds are filled with a plastic paste and two needles are lowered upon the cement at different intervals, penetrating more or less into the mortar according to the progress of setting. The depth to which each needle enters the mortar is recorded on a drum by two separate pencils. After each strike of the needles the drum turns a little and the table on which the moulds rest advances a step from right to left. The needle holders are lowered and raised by lever, which is set in motion by a spiral spring; a clock movement lets loose a governor and stops it again when the strike of the lever is completed. The diameter of the needle is 1 mm. Each needle holder weighs 300 grams.

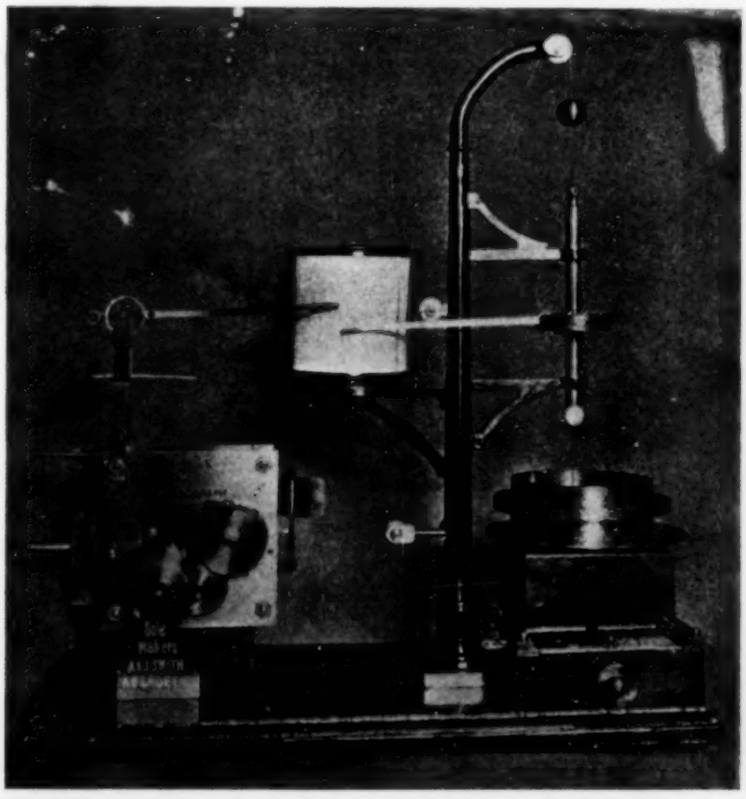


FIG. 4.—NICOL SPISSOGRAPH.

The Nicol Spissograph, Fig. 4, the invention of R. Gordon Nicol, of Aberdeen, Scotland, and made by A. & J. Smith, of that city, is similarly designed. This apparatus consists of a clockwork which raises and lowers every three minutes a pointed needle; at the same time the paste is rotated in a spiral to present a different spot to the needle at every contact. On the apparatus is a thermograph recording on the same chart the temperature of the air at the time the test was made. The whole is covered with a glass case and arrangements are made to keep the temperature and humidity regular.

One of the best achievements in this line has been Gary's apparatus and the resulting investigations. He used the thermal changes during setting as the basis of study, and by photographing the changes of the mercury columns secured data

*Z. physik. Chem. 70-146.

for a chart. Such a record as was thus secured, Fig. 5, gives admirable indications of the energy at work. None of these automatic instruments has been used in this country as far as I know.

The following is an extract from the official report of R. Feret, Boulogne-sur-Mer, at the Fifth Congress of the International Society for Testing Materials, held at Copenhagen in 1909:

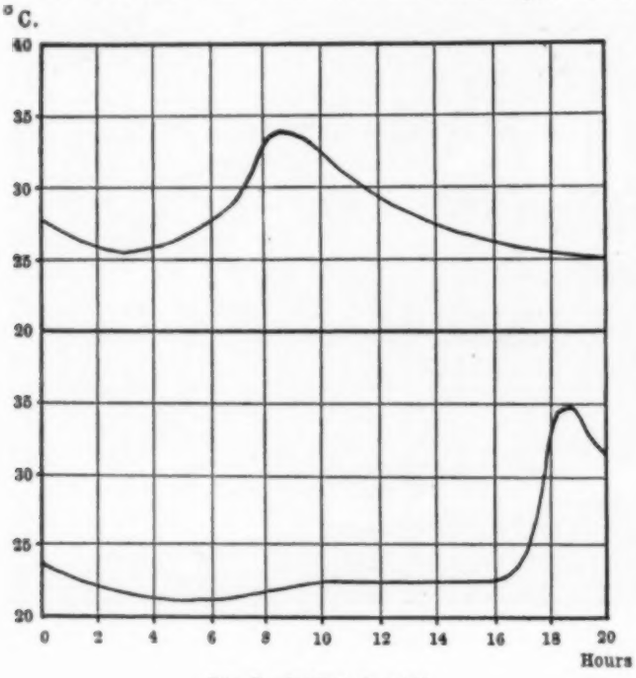


FIG. 5.—RECORD OF GARY.

Duration of Setting.

"The use of the Vicat Needle continues to be the only practical method in use for the determination of the duration of the period of setting of hydraulic cements. The appliance is of extreme simplicity, but its readings are sometimes uncertain, especially when it is a question of determining the end of the period; besides, the readings are of a purely conventional character and do not appear always to bear a sufficiently constant relation to the duration of the setting period of the mortars of actual practice. The discovery of more exact methods has therefore been attempted. Methods of testing based on the measured variations in the electric resistance of mortars while hardening have not given results of interest.

"Other investigations have aimed at the definition of the setting by the determination of the temperature of the mortar during its continuance. Reasonably regular curves were obtained by this method, which, however, were dependent on the testing conditions and corresponded with chemical phenomena, the relation of which to the change of consistency called setting has not yet been quite clearly established.

"The principal nature of the method to be employed may be the ascertainment of the time, reckoned from the commencement of the gauging, during which a given mortar can, with impunity, be further used without having to be revived by a fresh addition of water or a too violent mechanical treatment."

Reading this I was led to take up again certain studies of setting which I had made some years before, in which I was observing the resistance to penetration by glass rods, and the resistance to withdrawal of glass threads progressively acted upon by the salts and compounds formed in the paste and operating during the setting process. I thought that the holding power of newly formed salts upon glass might be progressively observed. Also it seemed to me then that the testing of the surface by wire points showed a lack of effectiveness in determining set in colloids and crystallo-colloidal binding agents. Penetration along a plane similar to shear by a knife blade should give better results than mere resistance to rupture of a surface at one point, just as the cutting of metal by a turning tool affords a better test of cohesion than indentation or scratching does.

If several glass rods or pins, ten or fifteen-thousandths of an inch in diameter, are driven into soft paste of plaster or cement, and at intervals are tipped forward, they will cut the mass at first considerably; later to a diminishing extent; and finally when the colloids and crystals are both well formed about the pins (a period corresponding with the final set or resistance to the light wire heavily loaded), they snap off sharply and suddenly. Such a combination seemed to give indications of very fine and measurable differences.

Now, if you were to bring up against a line of such pins a glass rod which had been smoked, you ought to get markings on it making a record showing relatively the resistances to penetration.

It seemed to me that this afforded a means of operating a graphic and chronological method, and I have made many models of apparatus for such a purpose by making simple adaptations of things at hand till the present model was developed and put lately into this final form by Messrs. Schneider Bros., of Jersey City, the gifted mechanicians who are known all over the world for the simplicity and beauty of their work on scientific instruments.

I will explain in as few words as possible the operation of this instrument, Fig. 6. It consists of a screw *H* operated by clockwork, giving two speeds, there being a shifting lever *L* for a speed of 1 in. an hour and another speed of double that. It can also be operated by hand through a knurled head at one end. This screw *H* carries a moving finger *F* projecting over a long rectangular paste mould *C*. This moves forward and strikes successively the glass pins *P* inserted deeply into the paste and projecting vertically from it in one line. As each glass pin bends forward it bears against a smoked glass rod and traces its path until when a distinct resistance is attained it snaps off. Back of this is an adjusting frame to carry the glass rod, and this can be brought forward very delicately, or drawn back, by the aid of a fine adjusting screw

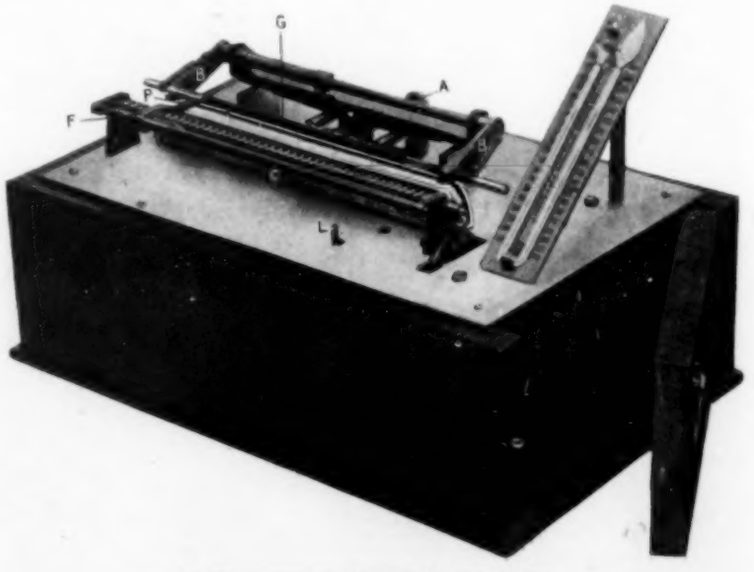


FIG. 6.—MCKENNA RECORDING APPARATUS.

A at the back. A metal mould is filled with freshly gauged cement and run into place between the screw and the adjusting frame. The glass rod which has been previously smoked and then rubbed clean over one-half of its surface, is inserted in the frame and brought forward over the center of the paste so that against the clean part of its surface these little pins are guided by it as they are inserted. So far as my investigations have gone I find that fifteen one-thousandths of an inch (.015") give strength enough for meeting resistance, at the same time giving a tendency to snap. They are pushed in vertically along the middle line ½-in. apart; the glass rod is drawn back by the screw *A* and the untouched smoked part is turned over so that it can be brought up against the pins by the screw again, ready for any record. Then the clock is started, the finger begins to move, and as it strikes each pin successively it makes the respective record of the resistance to penetration at that point and time. A maximum and minimum thermometer may be attached to the base plate.

When everything is thus arranged the top glass case can be put over it, leaving a small dish of water in the case, and the whole may be left, for instance, over night. In the morning the entire record is on a glass rod. Records thus made resemble somewhat the markings in Fig. 7.

(The record given for plaster of paris is not symmetrical as to time, as the record shows.)

These glass rods, with the records upon them, can be varnished and preserved for examination at any time, or the record can be photographed on sensitive paper and thus preserved.

From plaster of paris I obtained a simple record of differences in resistance to penetration. I have not had many opportunities to experiment with varieties in this substance, but I expect to find that the instrument will readily indicate the differences due to changes in percentages of water, catalytic agents, etc.

From Portland cement the first few records already obtained are most interesting. It seems that in every normal Portland cement I have thus tested there is observable in or about the third hour an indication of a relaxation of the stiffness first obtained and then a resumption of hardening. Comparing these results with those of Gary's thermal studies, it is seen that he observed a marked lowering of temperature at or about the third hour. If we consider again the most modern theories of setting, I think we can explain this. The cooling effect of course is at the period when salts are going into solution most rapidly.

It is well known that if a break occurs in a temperature-solubility curve which is otherwise continuous, it is a proof that the solid substance which is in equilibrium with the solution has passed into another form at the temperature of the break. We have the reverse of this in our record of cohesion, namely: the break in continuity of the marks of increasing cohesion indicates the separating out from a saturated solution of a greater proportion of still another component, and that the water thus freed permeates the colloid and softens it. Later, by dessication, by absorption of the water within and further crystallization, cohesion begins to increase and impenetrability and hardness go on. The discovery of this slack period or reverse set explains contradictions experienced in the past in measuring or determining the initial set by the surface penetration system. It probably also will explain anomalies occurring in the practical use of cement during the first hours of gauging fresh cement.

If this observation of change in the order of setting should prove to be universal for cements with the sulphate of lime additament, we may have to observe first *initial set*, then *reverse set*, and lastly *final set*, and distinguish between them in time and character.

It is my intention to continue work as opportunity presents on this instrument, which appears to be simple and useful, and in time we may hope to reach a little further in our knowledge of the setting of plasters and cements.

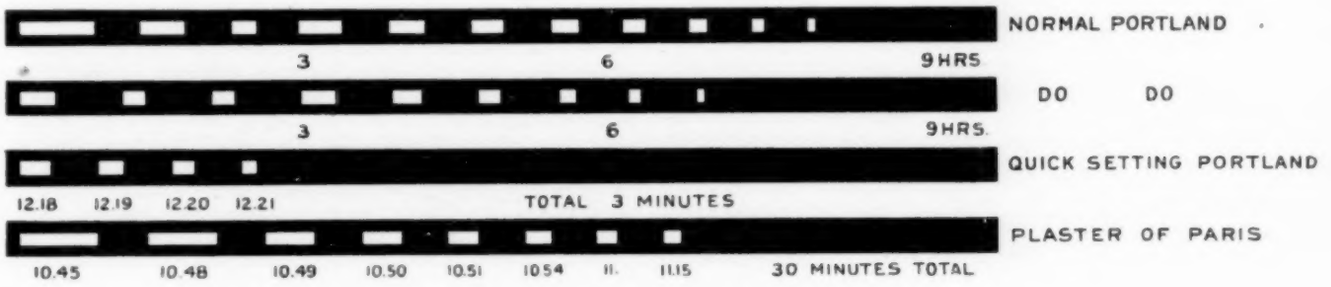


FIG. 7.—COMPARATIVE RECORDS.

Chemistry and Metallurgy in Great Britain.

(From our Special Correspondent.)

1911—A Retrospect.

It is rather difficult to review the year now closing, for it has been of an unusually variegated character. On the one side the pomp and splendor of state ceremonies—on the other political stress and strife—outside our own bounds vexed questions of international polity with the war dogs of all Europe straining at their leashes—at home great trade activity, with labor unrest, rioting, the use of troops.

All of these divergent forces must have their after effects, and we cannot enter on 1912 with a wholly clean slate. Internationally the rivalry in naval armaments has not yet reached its culmination. Industrially, we have at the moment of writing a big lockout in the cotton industry on a matter of principle which, if continued, must react on the local engineering and chemical trades. If very lengthy it will incidentally influence the price received for raw cotton in New Orleans. Of still greater moment is the risk of a big coal strike in eight or nine weeks' time. Yet in spite of all these troubles past and potential, trade has been and is phenomenally good, unemployment (other than that due to industrial disputes) has reached a minimum, and large engineering works are booked up with from six to twelve months' work.

No epoch-making inventions or discoveries will seemingly be associated with 1911 so far as chemistry or metallurgy are concerned. A steady progress toward commercial success has characterized chemical and electrochemical firms alike. Improvements in the price of copper must react favorably on the aluminium industry.

As regards the electrolytic alkali processes, the Castner-Kellner concern is phenomenally successful. The electric furnace is becoming better appreciated, but has not yet caught on to any large extent in this country.

The immediate future seems satisfactory in all spheres. Industrially we have plenty of work. Scientifically we are well occupied in perfecting processes and co-ordinating past discoveries and inventions. Financially the money market is easy. But at the back of this there are three realized factors, each inimical to peaceful progress. There is the danger (fortu-

nately less pressing than four months back) of a titanic struggle in the North Sea for the maintenance of our Empire. There is a world-wide rise in food prices, depressing the food-wages of the worker, and there is the labor unrest partly engendered by these high food prices. With the times thus out of joint, we are blessed with too many well-meaning sentimental amateurs, each persuaded of his heaven-inspired destiny to set them right. But to mention even one of these would be out of place in this letter.

The Purification of Water by Forced Oxidation.

At Cardiff, Reading, Tunbridge Wells, and elsewhere, a new system of purifying water is in operation, with results which are apparently satisfactory. The "Candy" apparatus consists of a strong steel cylinder, the lower part of which contains the filtering media—fine silica grit, sand, and a special substance termed "oxidium."

The water to be purified is forced into the cylinder at a pressure of from 5 lb. to 25 lb. per square inch, according to the character of the water, and compresses the air in the upper portion thereof, thus increasing to a considerable extent the quantity of oxygen dissolved in the water; and, in cases of highly impure water, the air supply may be maintained at the necessary rate by means of a small force-pump. Under the ordinary conditions of filtration, water containing iron will retain practically all the iron in solution, and will subsequently deposit oxide of iron in reservoirs, cisterns, or other receptacles, in which it may be store, as a consequence of gradual absorption of oxygen from the air. But this new apparatus so rapidly affects the oxidation of dissolved iron compounds in the water that the water leaves the filter practically free from iron.

Organic matter, too, appears to be thoroughly removed by this apparatus. The cleansing of the filter is easily carried out by reversing the flow of water, and it is stated that the quantity of water required for washing does not exceed 0.75 per cent of the quantity filtered. With a filter 8 ft. 3 in. in diameter some 9000 gal. per hour can be dealt with; and the capital cost for the average sand filter is put at about £15 per 1000 gal. working capacity per day, while the capital cost of the apparatus under consideration is stated to be only from £3 to £4 per 1000 gal. working capacity per day. Working expenses are stated to show a similar saving, being put at 1s. per 1,000,000 gal. for the "Candy" apparatus, and at 3s. to 5s. per 1,000,000 gal. for ordinary sand filters.

An Oil Fuel Process for Steel Castings.

In a recent issue of the *Times* a correspondent describes the Stock steel process, which is especially suitable for the production of small and intricate castings, and has been in operation at several works in the north of England and at, at least, one well-known works near London for over a year.

It is essentially the Bessemer process, in which hematite pig-iron is first melted by a blast of a mixture of high-pressure hot air and oil directed on to the surface of the charge; hot air alone being subsequently blown under pressure on to the molten metal to remove silicon and excess of carbon.

The plant consists of an oval converter lined with firebrick, mounted with trunnions on a turntable revolving horizontally. After heating for about half an hour the converter is placed horizontally to receive the charge of pig, and is then moved a quarter-circle into the melting position. The air from the blast is heated to about 800° Fahr., and has a pressure of ¾ lb. per square inch. The time required to melt the metal is about 60 minutes, when the converter is placed in a vertical position and the oil supply stopped.

A blast of hot air, at a temperature about 150° lower than that of the waste gases, is then played on to the metal and the slag removed. Silicon is got rid of by oxidation and the molten material consists of iron and carbon. Oxidation of the carbon now begins; the monoxide burns, and when the flame becomes dull, broken glass is thrown in to make a good slag and the air blast is shut off. The addition of ferro-manganese or spiegel, in quantity sufficient to act with the residual oxides, is made, and the metal is rabbled for pouring.

As a consequence of the efficient utilization of heat from the waste gases the molten metal attains a very high temperature, and the consequent liquidity permits a ready combination of alloys to produce special qualities of metal. The castings can be made in intricate molds, and do not need annealing. They show a high tensile strength and very good elongation. Allowing 13 per cent for loss in conversion and 3¼ per cent for spillings, etc., the cost of the molded metal is said not to exceed £5 per ton when hematite pig is employed, and the cost of electric power for a blower consuming 42 units is not more than 0.6d. per unit.

Market Prices, December, 1911.

Copper has shown a decided upward tendency. Opening at £59 it had risen to £60.15.0 by the 12th, and £62.5.0 by the 18th. Though a slight decline then set in, it closes at £63.10.0 in good demand.

Tin opened at £203, but took a sharp dip downwards from the 4th to the 11th, reaching £197 on that date. From the 13th it shot smartly up again and closes at £206.

Lead has been steady, if anything slightly inclined to go down. Opened at £16.3.0 and closes at £16.2.6.

Haematite has risen to much the same extent as Scotch pig, opening at 63/- and closing at 66/-.

Scotch Pig has been strong, rising from 54/- on the 1st to 55/8 on the 18th. Closes at 56/6.

Cleveland has followed the same course as Scotch pig, opening at 47/9 and closing at 50/8.

India Rubber opened at 4/4 and reached 4/5½, but has, on the whole, been steady and quiet. Closes at 4/3½.

Alum, lump, loose, per ton	5.12.6
Antimony, black sulphide powder	20. 0.0
Borax, British refined crystal, per ton	16. 0.0
Copper ore, 10 to 25 per cent, per unit	10/9 to 11.3
Copper sulphate, per ton	23. 0.0
Carbolic acid, liquid, 97/99 per cent, per gal	1.8
Camphor, 1-oz. tablets	1.9½
Caustic soda, ash 48 per cent ordinary, per ton	5.10.0
Creosote, ordinary good liquid, per gal	3
Hydrochloric acid, per cwt	5.0
Mica, small slabs, original cases, per lb	6d. to 2.0
Platinum, per ounce, nominal	9. 5.0
Petroleum, Russian spot	6⅛
Quicksilver, per bottle	8. 2.6
Sal ammoniac, lump, first delivered U. K., per ton	42. 0.0
Sulphate of ammonia, f.o.b. Liverpool, per ton	14. 5.0
Sulphur, recovered, per ton	5. 0.0
Shellac, standard T. N., orange spots, per cwt	4. 4.0
Tin ore, 70 per cent, per ton	£122 to 124. 0.0
Zinc, Vieille Montagne, sheets	30.15.0

The following differences will be noted:

Rise.

Copper ore, per unit	£0. 1.2
Copper sulphate, per ton	2. 5.0
Carbolic acid, per gal	1
Petroleum, per gal	0⅝
Zinc, v.m. sheets	12.6
Copper, per ton	4.10.0
Tin, per ton	4.10.0
Haematite	3.0
Scotch pig	2.9
Cleveland	2.11

Fall.

Quicksilver, per bottle	7.6
Sulphate of ammonia, per ton	3.9
Tin ore	2. 0.0
Lead, per ton	1.3

Sinter-Roasting with Dwight-Lloyd Machines at Salida, Colo.

Editorial Correspondence.

The advent and success of the various forms of sinter-roasting, or blast-roasting, particularly in connection with western lead smelting, is a good index of a marked change which has occurred in the mining industry in the past decade. We refer to the decline in the production of crude ore suitable for direct smelting in the blast furnace, and the coincident increase in the quantity of concentrates produced.

The latter condition was the cause of some concern to smelters, for the major portion of ore offered was not in condition for blast furnace smelting, nor was this condition materially improved by roasting in hand reverberatory or mechanical roasters. The capacity of blast furnaces was reduced, and an excessive quantity of flue dust formed which was even more difficult to treat than the original fine ore. Briquetting of roasted concentrates and flue dust, with lime as a binder, was introduced at some plants in an effort to convert fine material into a suitable blast furnace feed, but this proved an expensive additional process and was never regarded as a good solution of the problem. The real need of the lead smelter remained unfilled until the sinter-roasting systems were developed.

The first of these to gain commercial prominence in the United States was the Huntington-Heberlein pot-roasting system, which was installed at the plants of the American Smelting & Refining Company. Like many inventions which are pioneers in their lines, the Huntington-Heberlein system did not embody all the virtues of sinter-roasting which have since been developed, although it was a great step in advance over forms of roasting used previous to its development. It had inherent disadvantages which were not fully appreciated until they appeared in actual practice, or were accentuated by the improvements made in other types of sinter-roasters. It was intermittent in operation: used an upward draft through a deep bed of ore; subjected the entire charge to the blast for a long period of time; and finally, produced a mass of sinter weighing from 6 to 9 tons, which required a great deal of labor in breaking it for the blast furnace.

In contrast to this process is that of Dwight and Lloyd, which was evolved in an effort to overcome the disadvantages of pot-roasting. The time of exposure to heat is short, and the possible loss by volatilization correspondingly small; the process is continuous and gives an evenly sintered cake which is suitably broken in its discharge from the machine; the draft is downward through a comparatively thin bed, thus obviating the production of fine unsintered ore.

In an interesting contribution to the School of Mines *Quarterly*, for November, 1911, Mr. A. S. Dwight compares the efficiency of various forms of roasters, taking as a factor the number of pounds of ore treated per day on a square foot of furnace hearth. The following table embodies his estimates of various forms of roasters.

Efficiency of Roasters.

	Efficiency Factor, Pounds Ore Treated per Day per Sq. Ft. of Hearth
I. Roast heaps and stalls	5 to 20
II. Reverberatory roasters:	
1. Hand roaster	24 to 35
2. Mechanically stirred:	
average conditions	33 to 75
special conditions	150
3. Revolving cylinders	128
III. Blast roasting in pots	500 to 900
average	600
IV. Blast roasting in thin layers:	
1. Intermittent down-draft pans	1000 to 2000
2. Continuous sintering machines	2200 to 3000

Description of Salida Plant.

Different types of the Dwight-Lloyd machine have been invented, but the straight-line, continuous type is probably most familiar. At the Salida smelter of the Ohio & Colorado Smelting & Refining Company, three large, straight-line machines have been installed, in addition to a small one which was used experimentally. The accompanying drawing shows the general arrangement of the roasting plant.

The Dwight-Lloyd machine consists essentially of a traveling sectional hearth, feed hoppers, ignition furnace, suction box, fan, and driving gear, supported by a framework of structural steel. The hearth comprises a continuous line of forty-four sections or pallets, traveling around sprocket wheels at each end of the frame. The charge is delivered onto the hearth at one end, passes successively under the igniter and over the suction box, and is finally discharged as sinter at the other end. Each section of the hearth is 24 in. wide, 42 in. long and 4½ in. deep, and composed of three herring-bone grates each 8 in. by 42 in.

The grates originally provided with the machine were found too light, and breakage was excessive. Those now used are heavier, having only four-fifths as many slotted openings as the former grates, with a greater flare from top to bottom of slot. These grates have given better satisfaction, both as to durability and freedom from accretions which obstruct the draft.

The rate of travel of the hearth is regulated by cone pulleys. At maximum speed it moves at the rate of 1.6 ft. per minute, and at this speed the machine has a capacity of about 75 tons in 24 hours. The roaster foreman varies the speed according to the condition of the charge and the efficiency of the roast, basing his judgment on the appearance of the sinter as it breaks into cakes prior to being discharged. The cake should show that sintering has progressed down the grates.

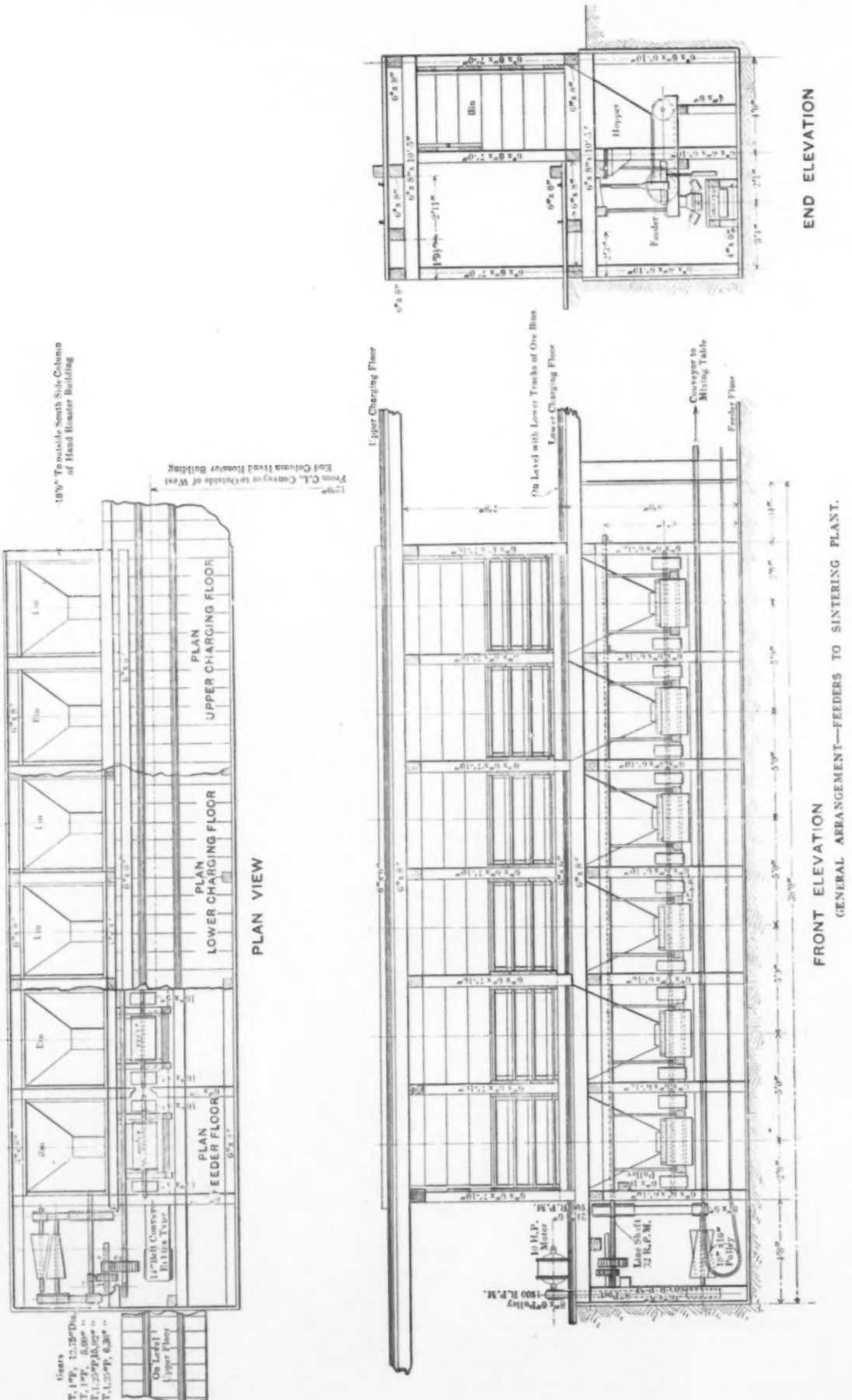
The charge comprises both coarse and fine material, each being delivered from a separate hopper, the bottom opening of which is designed to deposit a bed of definite depth. The coarse material ranges in size from ½ to 1 in., and forms a porous bed on the grates about 1 in. deep, on which the regular charge is then delivered, giving a total depth of bed of 4 in. The charge is ignited from a suspended coal-fired stove in which a bridge wall directs the flame so that it impinges on the surface of the charge. The area exposed to ignition is 12 in. by 42 in., and the time of exposure averages from 35 to 40 seconds. Fuel consumption is light. At Salida one ton of coal will ignite 185 tons of charge, equivalent to about 11 lb. of coal per ton of charge. Gasoline burners were tried first, but proved unsatisfactory, particularly in igniting the charge at the sides of the hearth.

The moving hearth makes an air-tight joint with the suction box over which it travels. The size of the box determines the effective hearth area of the roaster, which is 42 in. by 264 in., or 77 sq. ft. At the ordinary speed of the hearth the charge is exposed to ignition and suction for 12 to 14 minutes. The efficiency factor of the roaster at 75 tons per day with a hearth area of 77 sq. ft. is approximately 1950 lb. per square foot per day.

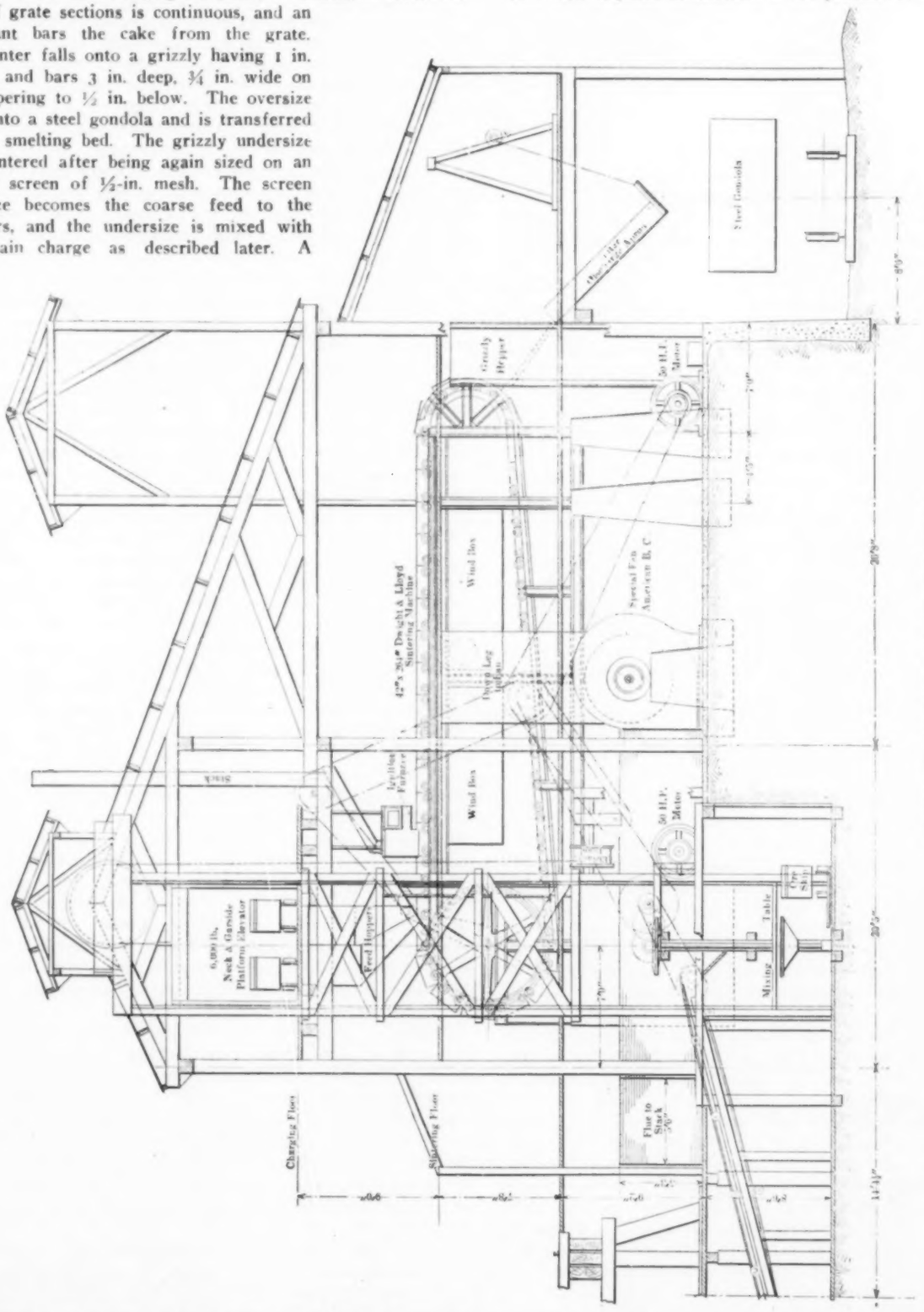
The fans used at Salida are specially constructed, being heavier and of better design than those originally installed. The old fans were mounted at one end of a shaft, the latter being supported in bearings at the other end. With this construction the fan easily got out of balance due to accretions which formed by the action of the roaster gases on the metal. The result was a high cost of maintenance and poor satisfaction generally. In the new fans the impeller is mounted centrally on a shaft which is supported at each end, outside and independent of the fan housing. The bearings are water-cooled, and rest on blocks of oak on concrete piers, the wood serving to give a slight flexibility to the construction.

The fans are 66 in. in diameter with impeller blades 7 in. wide. They revolve at 720 r.p.m., each being driven by a 50-hp motor. At this speed they induce a pressure of 4.6 oz. per square foot, equivalent to 8 in. of water.

In some installations, for example at Trail, B. C., described in this journal for August, 1911, page 405, one of the grate


END ELEVATION
Bin
Hopper
Feeder
FRONT ELEVATION
GENERAL ARRANGEMENT—FEEDERS TO SINTERING PLANT.
Upper Charging Floor
On Level with Lower Tracks of Ore Bins
Lower Charging Floor
Conveyor to Mixing Table
Feeder Floor
10 H.P. Motor
Line Shaft 32 R.P.M.
PLAN VIEW
PLAN UPPER CHARGING FLOOR
PLAN LOWER CHARGING FLOOR
PLAN FEEDER FLOOR
On Level Upper Floor

sections is left out of the line, so that on arriving at the discharge end each pallet falls a distance of 2 ft. against the one preceding it, thus dislodging the cake. At Salida, however, the line of grate sections is continuous, and an attendant bars the cake from the grate. The sinter falls onto a grizzly having 1 in. spaces and bars 3 in. deep, ¾ in. wide on top tapering to ½ in. below. The oversize falls into a steel gondola and is transferred to the smelting bed. The grizzly undersize is resintered after being again sized on an impact screen of ½-in. mesh. The screen oversize becomes the coarse feed to the roasters, and the undersize is mixed with the main charge as described later. A maximum of 25 per cent of grizzly undersize is thus returned to the roadsters, the exact quantity depending on the conditions of the roast.



GENERAL ARRANGEMENT OF SINTERING PLANT.

Components of the Roaster Charge.

The roaster charge is a mixture of the following ores and products:

(1) Partly roasted iron sulphide concentrate, containing about 15 per cent sulphur.

This iron sulphide concentrate is the product of three Godfrey rotating-hearth roasters used as preliminary desulphurizers of heavy sulphides.

(2) Raw lead concentrate.

(3) Raw silicious sulphide ore, low in sulphur and high in silica.

(4) Fine sinter returned from the impact screen.

These are the four components of the roaster charge.

The composition of the dry charge for the month of December, 1911, was as follows:

Lead	18.0	per	cent
Copper	1.0	"	"
Insoluble	24.6	"	"
Iron	21.2	"	"
Manganese	1.0	"	"
Zinc	7.6	"	"
Sulphur	15.4	"	"

Mixing the Charge.

The mixing device used at Salida is worthy of special mention as being automatic, accurate and adjustable in proportioning the several components of the charge. It was designed by Mr. F. D. Weeks, formerly superintendent of the smelter in Salida.

As illustrated on p. 88, it consists of a series of hopper bins, one for each kind of ore; conveyer belts, and a mixing table. The bottom of each bin is formed by a short belt-conveyer supported on rollers directly beneath the bin opening, and traveling around head and tail pulleys placed in front of and behind the bin, respectively. When in motion this feed belt carries from the bin a continuous layer of ore of uniform cross section, and discharges onto another belt-conveyer running at right angles to it.

The feed belt-conveyers travel intermittently, being actuated by eccentrics mounted on a shaft extending the length of the line of bins. The speed of this shaft is regulated by cone pulleys and can be varied from 20 to 80 r.p.m. The eccentrics have a throw of 4 in., which is never altered; but adjustments are provided on the eccentric rods whereby all or any fraction of the throw can be applied to the head pulley of the belt-conveyer, thereby imparting an intermittent movement to the belt.

The distance traveled by the belt at each throw of the eccentric may be varied from 2 in., at full throw, to zero; 3/32 in. being the shortest actual travel. By an arrangement of friction pulleys, all tendency toward a reverse travel of the belt is overcome.

Thus each feed belt-conveyer may be made to travel a variable distance with variable frequency, delivering from its corresponding bin a quantity of ore proportionate to the distance traveled per minute. For the convenience of the metallurgist and the guidance of the operator in varying the proportions of the charge, an indicator is attached to the head pulley of each feed-belt, consisting of a pointer moving across an arbitrary scale at each revolution of the eccentric.

The main belt-conveyer delivers the charge to a cast-iron annular mixing table, 8 ft. in diameter, revolving at a speed of 2 r.p.m. The belt discharges above the center of the table, and the falling ore tends to form a cone. Stationary vertical rabble blades spread the ore toward the periphery of the table where it is drawn off into cars and elevated to the roaster bins. A spray of water plays on the ore while it is being mixed, adding about 10 per cent moisture to the charge.

The use of sinter-roasting seems bound to increase for reasons already given. In fact, a smelter which is not equipped with some form of this process will find it increasingly difficult to compete with plants so equipped. The recent closing of a Colorado smelter may be assigned in large measure to inadequate means for treating concentrates. At Salida the blast furnace charge is now largely composed of Dwight-Lloyd sinter, and the effect on furnace capacity is very satisfactory. Two blast furnaces, one 44 in. by 144 in., and the other 44 in. by 180 in., are now treating 440 tons of charge in 24 hours, a record which would be impossible under present conditions without sinter-roasting.

We acknowledge the courtesy of Mr. F. D. Weeks, of the American Metals Company, and Mr. E. H. Laws, superintendent of the Salida plant, in permitting the publication of the drawings and data here given.

Geophysical Research.[1]

By Arthur L. Day.

To write the history of the earth is a very different undertaking from writing the history of a people. In the latter case a diligent seeker can usually find some ancient monastery where far-sighted historians of an earlier generation have collected the more important records which he requires and placed them within reach of his hand. With the earth's history, which is the province of geology, it is another matter.

The great globe has been millions of years in the making, and except for a mere fragment of its most recent history it has had neither a historian nor an observer. Its formation has not only extended over an almost incomprehensible interval of time, but we have no parallel in our limited experience to help us to understand its complicated development and no system of classification adequate to the task even of grouping in an orderly way all the observed rock and mineral formations with reference to the forces which moulded them. And even if we could correctly interpret all the visible rock records, we are still quite helpless to comprehend all those earlier activities of the formation period whose record is now obliterated.

To the student of the earth's history, therefore, the problem of gathering and ordering such a widely scattered and heterogeneous collection of effects and causes is one of somewhat overwhelming scope and complication. In the industrial world a situation of this kind soon results in replacing individual effort with collective effort in the organization of a system of a scope more appropriate to the magnitude of the task. We are familiar with industrial organization and the wonderful progress in the development of American industries which has everywhere followed it. We are also familiar with organized geological surveys and the success which has attended them in geological and topographical classification. But the idea of organizing research to meet a scientific situation of extraordinary scope and complexity is still comparatively new. The very words science and research are still regarded as referring to something out of the ordinary, something to be withheld from the common gaze, to be kept hidden in a special niche, behind a mysterious curtain and served by priests of peculiar temperament and unpractical ideals. This is both disparaging to our good sense and prejudicial to the progress of knowledge. Scientific research is not a luxury; it is a fundamental necessity. It is not a European fad, but is the very essence of the tremendous industrial success of the last 20 years.

Professor Nichols, of Cornell, as retiring president of the American Association for the Advancement of Science, put the case in this way: "The main product of science (research) is knowledge. Among its by-products are the technologic arts, including invention, engineering in all its branches and modern industry." The idea of scientific research is therefore not less tangible than industrial development, or less practical; it is merely one step more fundamental; it is concerned with the discovery of principles and underlying relations rather than their application. This being true, research should profit as much, or even more, from efficient organization as industrial development has done.

Although this conclusion is making its way but slowly in American science, in geological research, where material must be gathered from the utmost ends of the earth and even from within it, and where nearly every known branch of scientific activity finds some application, there is a peculiarly favorable opportunity for organized effort which is already coming to be recognized. "So long as geology remained a descriptive science," says President Van Hise, of Wisconsin, "it had little need of chemistry and physics; but the time has now come when geologists are not satisfied with mere description. They desire to interpret the phenomena they see in reference to their

[1]Presidential address delivered at the 700th meeting of the Philosophical Society of Washington, November 25, 1911. From the *Journal* of the Washington Academy of Sciences.

causes—in other words, under the principles of physics and chemistry. . . . This involves co-operation between physicists, chemists and geologists."

In a general way, physics, chemistry and biology have already supplied working hypotheses which have been used by students of geology to help in the examination, classification and mapping of the most conspicuous features of the exposed portion of the earth. The geologist has gone abroad and has studied the distribution of land and water, the mountain ranges, the erosive action of ice and of surface water and the resulting sedimentary deposits, the distribution of volcanic activity and of its products, the igneous rocks; or more in detail he has studied the appearance of fossils in certain strata, and has inferred the sequence of geologic time. The distribution of particular minerals and of ore deposits has been carefully mapped. Regions which offer evidence of extraordinary upheaval through the exercise of physical forces have been painstakingly examined and so on through the great range of geologic activity.

In a word, the field has been given a thorough general examination, but the manifold problems which this examination has developed, although early recognized and often the subject of philosophical speculation and discussion, still await an opportunity for quantitative study. They are often problems for the laboratory and not for the field, problems for exact measurement rather than for inference, problems for the physicist and chemist rather than for the geologist. This is not a result of oversight, it is a stage in the development of the science, first the location and classification of the material, then the laboratory study of why and how much.

Certain indications have led us to believe, for example, that the earth was once completely gaseous and in appearance much like our sun. Indeed, it possibly formed a part of the sun, but through some instability in the system became split off—a great gaseous ball which has cooled to its present condition. The cooling probably went on rapidly at first until a protecting crust formed about the ball, then more and more slowly, until now, when our loss of heat by radiation into space is more than compensated by heat received from the sun.

Obviously, the earliest portions of this history are and must remain dependent upon inference, but the formation of a solid crust cannot advance far before portions of it become fixed in a form such that further disturbance does not destroy their identity. From this point on the history of the earth is a matter of record and can be interpreted if only we have sufficient knowledge of the mineral relations through all the stages of their development.

It must have been a very turbulent sea, the molten surface of our earth upon which the rocky crust began to form. The first patches of crust were probably shattered over and over again by escaping gases and violent explosions of which our waning volcanic activity is but a feeble echo. If the earth was first gaseous, and the outer surface gradually condensed to a liquid, its outer portions at least must have been whirled and tumbled about sufficiently, even in a few thousand years (which is a very small interval in the formation of an earth), to mix its various ingredients pretty thoroughly. It has accordingly been hard to see just how it came to separate into individual rocks of such widely different appearance and character.

Of course, the number of its ingredients was large. We have already discovered 80 or more different elementary substances in the earth, and there is an almost endless number of more or less stable compounds of these. The freezing of an earth is therefore different from the freezing of pure water, but the freezing of salt water offers a clue to the explanation of the way in which the earth solidified as we find it. When salt water freezes, the salt is practically all left behind. The ice contains much less salt and the remaining water relatively more salt than before freezing began. Applying this familiar observation to the supposed molten surface of the earth as it begins to solidify, we have a suggestion of order and reason in its separation into so many kinds of rocks.

Now, it happens that in the recent development of chemistry much attention has been given to the study of solutions of various kinds, and a great body of information has been gathered and classified of which our observation upon the freezing of salt water is a simple type. Still more recently (quite lately in fact) it has occurred to many students of the earth that here lies not only the clue but perhaps the key to their great problem. If the individual components which are intimately mixed in solution separate wholly or partially in some regular way upon freezing—and nearly all the solutions which have been studied appear to show such segregation—we have a quantitative system which will probably prove adequate to solve the problem of rock formation, provided only that the experimental difficulties attending the study of molten rock and the complications imposed by the presence of so many component minerals do not prove prohibitive. This is a very simple statement of the point of view which has led to the experimental study of rock formation in the laboratory as a natural sequence to statistical study in the field.

Geophysics therefore does not come as a new science, nor as a restricted subdivision of geology, like physiography or stratigraphy, but rather to introduce into the study of the earth an element of exactness, of quantitative relation. It may include physics or chemistry, biology or crystallography or physical chemistry, or all of these at need. The distinctive feature of geophysics is not its scope, which may well be left to the future, but its quantitative character. The Geophysical Laboratory of the Carnegie Institution of Washington has entered upon some of the investigations suggested by this long preliminary study of the earth—the physical properties and conditions of formation of the rocks and minerals. The Department of Terrestrial Magnetism of the same institution has undertaken another—the earth's magnetism; the German Geophysical Laboratory at Göttingen a third—the earthquakes—and these will no doubt be followed by others.

The first effect of calling exact science into consultation upon geologic problems is to introduce a somewhat different viewpoint. It has been our habit to study the minerals and the rocks as we find them to-day, after many of the causes which have had a share in their evolution have ceased to be active—after the fire has gone out. If we attempt to reconstruct in our minds the operations which enter into the formation of an igneous rock or of a body of ore, we must infer them from present appearances and environment.

The experimental geophysicist, on the other hand, confronting the same problem, says to himself: Can we not construct a miniature volcano in the laboratory; can we not built a furnace in which an igneous rock can be formed under such conditions that we can observe its minutest change? He proposes to introduce temperature measuring devices and apparatus for the determination of pressure, to investigate the character of the surrounding atmosphere and the quantity of water vapor which may be present. He insists upon the chemical purity of every ingredient which goes into the furnace and guards it carefully against contamination. In these various ways he will undertake to ascertain the exact magnitude of all the causes, both physical and chemical, which have been at work in his miniature rock-producer, together with the physical characteristics of the product.

A very practical question now arises. Can he do all this successfully at the temperatures where the minerals form? We must press this question and insist upon a satisfactory answer, for it is by no means obvious that the relations which the physicist and chemist have established at the temperatures of everyday life—energy content, density, solubility, viscosity, dissociation—will continue to hold when substances are carried up to a white heat.

The substances, too, are different from those with which the chemist and physicist have been generally familiar. Instead of simple metals, aqueous solutions and readily soluble active salts, we encounter silicates and refractory oxides, inert in

behavior and capable of existing together in mixtures of great complexity. We must, therefore, extend the range of our physics and our chemistry to a scope in some degree commensurate with the wide range of conditions which the earth in its development has passed through. Let us follow for a little the actual progress of such an attempt.

The first step is to provide the necessary temperatures. Obviously, the common fire-clay crucible and the smelter's furnace with its brick lining will not serve us here, for all these are themselves mineral aggregates. The charge, furnace lining and crucible would go down together in a fall as disastrous as Humpty Dumpty's. But experiment has taught us that platinum crucibles, magnesia furnace tubes inclosing an electrically heated helix of platinum wire, and electric temperature-measuring devices, provide a furnace in which nearly all of the important minerals can be successfully studied, which is hot enough to melt silver, gold, copper, nickel or iron readily, and where any temperature up to 1600° C. can be maintained perfectly constant if need be for several weeks. All these temperatures can be measured with no uncertainty greater than 5° C. This equipment preserves the chemical purity of the mineral studied and enables the temperature to be controlled and measured at every step of the experimental work. Or an iridium furnace tube and an iridium crucible can be substituted for platinum, the magnesia supports can still be used and we have it in our power to go on to 2000° C., which is quite sufficient for all the more important minerals which we know.

The physicist has, therefore, found a suitable melting pot, and means of ascertaining what goes on within the pot; but he at once encounters another difficulty. Nature has provided us with relatively few minerals of high chemical purity. If a natural mineral is chosen for experiment, however typical it may be, several per cent of other minerals may be expected to be present with it, the effect of which is at present quite unknown. Now the first axiom of the investigator in a new field who desires to undertake measurements which shall have a real value is that the number of unknown quantities in his equations must not be greater than he can eliminate by his experimental processes; in other words, he must begin with conditions so simple that the relation between a particular effect and its cause can be absolutely established without leaving undetermined factors. Having solved the simple case, it is a straightforward matter to utilize this information to help solve a more complicated one.

If we would, therefore, reduce the mineral relations to an exact science, which is our obvious purpose, it is necessary from the outset to prepare minerals of the highest purity and to establish their properties. Having obtained such a pure mineral type, it may be, and often is, in the power of the mineralogist and his microscope to determine by direct comparison with its natural prototype the kind and amount of effect actually produced in the natural mineral by the one or more other minerals which it contains. We have, therefore, hardly started upon our investigation before the need of an organized system is demonstrated—first comes the chemist, who prepares and analyzes the pure mineral for investigation; then the physicist, who provides and measures the conditions to which it is subjected; then the mineralogist, who establishes its optical properties in relation to the corresponding natural minerals.

Having prepared such a mineral, of high purity and of known crystalline character, we can ascertain its behavior at the temperatures which must have obtained during the various stages of earth formation. We can study the various crystal forms through which it passes on heating and the temperature ranges within which these forms are stable; we can also melt it and measure the melting or solidifying temperature.

Another mineral, prepared with the same care and studied in the same way, may afterward be added to the first and the relation of these two determined. If they combine, heat is absorbed or released, and this quantity of heat can be measured, together with the exact temperature at which the absorption or release takes place.

If the mixture results in the formation of one or more mineral compounds, we shall learn the conditions of formation, the temperature region within which the new forms are stable, and the changes which each undergoes with changes of pressure and temperature, as before.

If the new forms show signs of instability, we can drop them into cold water or mercury so quickly that there will be no opportunity to return to initial stable forms, and thus obtain, for study with the microscope at our leisure, every individual phase of the process through which the group of minerals has passed.

Without complicating the illustration further, it is obvious that we have it in our power to reproduce in detail the actual process of rock formation within the earth, and to substitute measurement where the geologist has been obliged to use inference; to tabulate the whole history of the formation of a mineral or group of minerals under every variety of condition which we may suppose it to have passed through in the earth, provided only we can reproduce that condition in the laboratory.

During the past quarter of a century there has arisen in the middle ground between physics and chemistry a new science of physical chemistry, in the development of which generalizations of great value in the study of minerals have been established. As long ago as 1861 the distinguished German chemist Bunsen pointed out that rocks must be considered to be solutions and must be studied as such; but inasmuch as comparatively little was known about solutions in those days, and the rocks at best appeared to be very complicated ones, no active steps in that direction were taken during Bunsen's life.

But in recent years solutions have been widely studied, under rather limited conditions of temperature and pressure, to be sure, but it has resulted in establishing relations—like the *phase rule*—of such effect and far-reaching character that now, just half a century afterward, we are entering with great vigor upon the prosecution of Bunsen's suggestion.

It is now possible to establish definite limits of solubility of one mineral in another, and definite conditions of equilibrium, even in rather complicated groups of minerals, which enables us not only to interpret the relations developed by such a thermal study as that outlined above, but also to assure ourselves that only a definitely limited number of compounds of two minerals can exist, and that they must bear a constant and characteristic relation to each other under given conditions of temperature and pressure, and that changes of temperature and pressure will affect this relation in a definite and determinable way.

Physical chemistry not only takes into account the chemical composition of mineral compounds, but their physical properties as well, throughout the entire temperature region in which they have stable existence, and, therefore, furnishes us at once with the possibility of a new and adequately comprehensive classification of all the minerals and rocks in the earth.

The value of an adequate system of classification appeals chiefly to those whose duties bring them into intimate relations with the subject matter of a science, but so much may appropriately be said that a consistent application of physical chemistry to the minerals may operate in the not far distant future to develop an entirely new conception of the science of mineralogy.

As the number and scope of such exact measurements increase we gradually build up what may be called a geologic thermometer. Just as the location of fossils offers a basis for estimating geologic time, it often happens that a mineral takes on a variety of different crystal habits, according as it happened to form at one temperature or another.

Quartz, for example, which is one of the commonest of natural minerals and one of the most familiar, undergoes two changes in its crystal form which leave an ineffaceable record. One occurs at 575° and the other at 800°. An optical ex-

amination of even a minute quartz fragment from the mountainside will reveal to the skilful petrologist whether the crystal formed at a temperature below 575°, between 575° and 800°, or above 800°. And if we could have at our disposal a great body of such exact measurements of the temperature region within which particular crystals originate and remain stable, we could apply that directly to terrestrial formations in which this mineral occurs, and read therein the temperature which must have obtained during their formation.

All this will not be done in the first year, and perhaps not in the first decade; but the ultimate effectiveness of this method of procedure in establishing the relations between the minerals and the valuable ores is now as certain of success as the operations of any of the sciences which have now come to be characterized as exact, as opposed to descriptive.

There is one important difference between the great laboratory of nature and its feeble human counterpart. Nature operated with large masses, mixed with a generous hand, and there was always plenty of time for the growth of great individual crystals, at which we marvel whenever we encounter them, and which we have sometimes come to regard highly as precious stones.

To carry these processes into the laboratory is necessarily fraught with certain limitations. The quantities must remain small and the time and available financial resources will always be limited. So long as we are able to ascertain the optical character of a crystal with equal exactness whether the crystal is of the size of the proverbial mustard-seed or a walnut, the scientific laboratory cannot properly afford the time necessary to produce the large crystals which nature offers so aboundantly.

Furthermore, the crystals of nature often owe their brilliant coloring to slight admixtures of impurity, which, to the scientific laboratory, spell failure and are avoided with the utmost care. Most of the mineral crystals, when reproduced in the laboratory, are quite colorless.

And so, although the question is often raised whether we are not really engaged in the artificial production of gems, and although the seductive character of such an investigation would no doubt appeal to many, it must be admitted that the geological laboratory is not and probably will never become the serious competitor of nature in those directions in which nature has produced her most brilliant effects.

In what has preceded I have laid emphasis upon the value of experimental measurements, in the systematic development of a more exact science of the earth. It is a fair question and one which is very often raised, whether all this investigation has a utilitarian side, whether the knowledge obtained in this way and with such difficulty, would help to solve any of the problems arising in the exploitation of our mineral resources or assist in our industrial development. It is neither wise nor expedient, in entering upon a new field of research, to expatiate long upon its practical utility. Its principles must first be established, after which there is no lack of ingenuity in finding profitable application of them.

The development of thermo-electric apparatus for the accurate measurement of high temperatures was begun and has been perfected in the interest of geophysical research, and it has already found such extended application among the technical industries as to demand the manufacture and calibration of thousands of such high-temperature thermometers every year. The tempering and impregnation of steel are no longer dependent upon the more or less trained eye of the workman, but are done at measured temperatures and under known conditions which guarantee the uniformity of the product and admit of adaptation to particular purposes, like high-speed tools or armor plate. This has the incidental but far-reaching industrial consequence that workmen of great individual skill in these industries are much less necessary now than formerly. Everything is accomplished by bringing temperature conditions under mechanical control and making them absolutely reproducible without the exercise of critical judgment.

A more intimate knowledge of the behavior of the minerals themselves finds almost immediate industrial application. An industry which has grown to enormous proportions in recent years is the manufacture of portland cement, about which little more has been known than that if certain natural minerals were taken in the proper proportions and heated in a peculiar furnace developed by experience, the resulting product could be mixed with water to form an artificial stone which has found extensive application in the building trades.

Chemical analysis readily established the fact that the chief ingredients in a successful portland cement were lime, alumina and silica, with a small admixture, perhaps, of iron and magnesia; but the relation in which these ingredients stood one to another—that is, which of them were necessary and which merely incidental—and in what compounds and what proportions the necessary ingredients required to be present, has never been satisfactorily established. When we know the stable compounds which lime, alumina and silica can combine to form, together with the conditions of equilibrium between these for different temperatures and percentages of each component, a formula can be written offhand for a successful portland cement from given ingredients somewhat in the same way as an experienced cook might write out the recipe for a successful dish.

Such definite and valuable knowledge is not within our reach. To obtain it requires, in fact, precisely the same system of procedure which has been described above and which has already been successfully applied to many of the natural minerals which have been reproduced and studied in the Geophysical Laboratory during the past five years.

It happens that we have examined a considerable number of these very mixtures in our recent work upon the rocks. All the compounds of lime, silica and alumina have been established, and a portion of the silica-magnesia series, and their relations have been definitely determined throughout the entire range of accessible temperatures. There is no reason to apprehend serious difficulty in applying the same procedure to the commercial ingredients of portland cement, and replacing the present rule-of-thumb methods and uncertain products with dependable cements. The problem of determining the relation of the ingredients in commercial cement and the conditions necessary for its successful formation is exactly the same in character as that of determining the conditions of formation of the rocks of the earth.

A physico-chemical investigation of the sulphide ores over a wide range of temperatures and pressures has also been undertaken, which has developed a large body of exact information of value in mining industry. And such illustrations could be continued almost indefinitely, if it would serve any useful purpose to do so.

The industrial world is not as a rule interested in scientific principles; the principle must first be narrowed down to the scope of the industrial requirement before its usefulness is apparent. The immediate effect of an industrial standpoint is, therefore, to restrict investigation at the risk of losing sight of underlying principles entirely.

An illustration of this has come down to us through the pages of history of a character to command and receive the utmost respect, for such another can hardly be expected to occur. We have honored the early philosophers for their splendid search after broad knowledge; but in what is now the field of chemistry they allowed themselves to be turned aside to the pursuit of a single, strictly utilitarian problem—the transmutation of base metals into gold. The history of chemistry is a history of this one problem from the fourth to the sixteenth century—twelve centuries before a man arose whose broader standpoint enabled him to divert the fruitless search into other channels from which a science has slowly arisen which is now so broad as to overlap most of the other sciences, and withal so practical that hardly an industry is entirely independent of it.

The so-called practical questions may therefore as well be left to take care of themselves. There has been no lack of ingenuity in making profitable application of systematic knowledge whenever the need for it became insistent, for the rewards of such effort are considerable. And it is no longer an argument against proceeding to establish relationships in a new field, that the scope of their application cannot be completely foreseen.

Now, what more promising questions occur to one than these: If the earth was originally fluid, as it appears to have been, and has gradually cooled down to its present state, its component minerals must at some time have been much more thoroughly mixed than now; how did they come to separate in the process of cooling into highly individualized masses and groups as we now find them, and what were the steps in their deposition? If the whole earth was hot, whence came the marble of which we have so much and which can withstand no heat? What has given us the valuable deposits of iron, of gold, of precious stones? What determines the various crystal forms found in the different minerals, and what is their relation? Some must have formed under pressure, some without pressure, some with the help of water, and some without. Where is the center, and what the source of energy in our volcanoes?

All these questions, and many more, the geophysicist may attempt to answer.

Geophysical Laboratory, Carnegie Institution.
Washington, D. C.

Methods of Balancing Chemical Reaction Equations.

By F. B. Wilson.

The Summation Method.

The basic ideas involved in the summation method here detailed are, first, the resolution of any complex reaction into a series of more or less probable simple stages; second, the adjustment of the preliminary equations so as to eliminate any assumed intermediate substance; third, the summation of the adjusted equations to arrive at the final balanced form of the complete reaction equation.

To systematize the procedures, all reactions have been arranged in four groups so that all of the members of any one group may be resolved by the arbitrary scheme peculiar to that group. The following examples will illustrate these points.

Inspection of the statement of any reaction will show that it is possible to place it in some one of the following classes:

Class I.—All reactions involving the action of an acid or an alkaline hydroxide on a metal.

Class II.—All reactions involving the action of an acid or an alkaline hydroxide on a salt.

Class III.—All reactions in which the action of an oxidizing agent is an essential feature.

Class IV.—All reactions involving combinations of some of the preceding cases and also those reactions that cannot be referred to any of the preceding groups.

CLASS I.

Reactions Involving the Action of an Acid or an Alkaline Hydroxide on a Metal.

The method to be followed in handling members of this class involves the resolution of the reaction into a series of stages in such a way that the first preliminary equation will be one showing the action of the acid or alkaline hydroxide on the metal and the production of a salt and nascent hydrogen.

If the general statement shows that the products are a salt and hydrogen gas only, then the reaction is a simple one-stage reaction. But if a gas other than hydrogen is one of the observed products, then the nascent hydrogen produced in the first stage must be used in other reaction equations in such a manner as to give rise to the required products. The following cases will be worked out to show the application of this method to reactions of the first class.

Example 1.

$$aZn + bH_2SO_4 + aq. = cZnSO_4 + dH + aq.$$

and

$$aZn + bKOH + aq. = cZn(OK)_2 + dH + aq.$$

From inspection of the statements it is evident that these are the simple cases in which the reaction is completed in one stage. The equations are balanced numerically by the adjustment of the quantity of hydrogen. The final forms are:

$$Zn + H_2SO_4 + aq. = ZnSO_4 + H_2 + aq.$$

and

$$Zn + 2KOH + aq. = Zn(OK)_2 + H_2 + aq.$$

Example 2.

$$aZn + bH_2SO_4 = cZnSO_4 + dSO_2 + eS + fH_2O.$$

Here a gas other than hydrogen is evolved, hence a second and third step will be required, showing how the action of the nascent hyydrogen on more molecules of acid gives rise to the SO_2, S and H_2O called for by the main statement. This is also a case where the use of the dualistic or oxide formulas will make the actions clearer.

(1) $H_2O{\cdot}SO_2 + Zn = ZnO{\cdot}SO_3 + (2H)$

(2) $H_2O{\cdot}SO_2 + (2H) = SO_2 + H_2O$

(3) $H_2O{\cdot}SO_2 + (6H) = S + 4H_2O$

Since all of the required products have been formed in these steps, no other steps are needed. So all that remains to be done is the adjustment that will permit the cancellation of the intermediate substance, active hydrogen. Eight atoms of hydrogen have been used, but two have been produced; therefore it will be necessary to repeat reaction (1) four times, or what amounts to the same thing, multiply all quantities in this equation by the factor four.

(1) $4H_2O{\cdot}SO_2 + 4Zn = 4ZnO{\cdot}SO_3 + (8H)$

The nascent hydrogen can then be eliminated on the basis of eight atoms and the sum of (2), (3) and (1′) will be the required balanced form.

$$6H_2SO_4 + 4Zn = 4ZnSO_4 + SO_2 + S + 6H_2O.$$

CLASS II.

Reactions Involving the Action of an Acid or an Alkaline Hydroxide on a Salt.

The first step in the resolution of a second-class reaction is the writing of an equation showing the action of the acid or alkaline hydroxide on the salt and the production of another salt and a new hydrogen compound.

The products of this preliminary equation may be the required substances of the general statement, this, then, being a simple one-stage reaction, or one or both of these products may be converted into the new combinations required to satisfy the demands of the main statement.

Example 1.

$$aNaCl + bH_2SO_4 = cNaHSO_4 + dHCl.$$

This is a case so simple in character that the mere writing of the preliminary equation completes the work.

$$H_2SO_4 + NaCl = NaHSO_4 + HCl.$$

Example 2.

$$aNa_2S_2O_3 + bHCl + aq. = cNaCl + dSO_2 + eS + fH_2O + aq.$$

The initial step is as follows:

(1) $2HCl + Na_2S_2O_3 = 2NaCl + (H_2S_2O_3).$

The resolution is then completed by writing the equation that shows the decomposition of the unstable thiosulfuric acid into the other substances required by the main statement. This will be:

(2) $(H_2S_2O_3) = H_2O + SO_2 + S.$

The $H_2S_2O_3$ is produced and decomposed in equivalent amounts in the equations as they stand, hence no adjustment is necessary previous to summing (1) and (2). The final form will be:

$$2HCl + Na_2S_2O_3 + aq. = 2NaCl + H_2O + SO_2 + S + aq.$$

Example 3.

$$aNH_4OH + bCuSO_4 + aq. = cCuSO_4(NH_3)_4 + dH_2O + aq.$$

Here, as in many other cases, it can be proved experimentally, by a suitable control of the conditions, that the reaction does actually proceed in two stages. The intermediate products, cupric hydroxide and ammonium sulphate, can be isolated as such. Therefore the regular preliminary equation represents a real and not an imaginary reaction.

(1) $2NH_4OH + CuSO_4 = [(NH_4)_2SO_4] + [Cu(OH)_2]$

Then the next step is:

(2) $[Cu(OH)_2] + [(NH_4)_2SO_4] + 2NH_4OH = CuSO_4(NH_3)_4 + 2H_2O$

The sum of (1) and (2) is the required final form and thus we find:—

$$4\,NH_4OH + CuSO_4 + aq. = CuSO_4\,(NH_3)_4 + 4\,H_2O + aq.$$

CLASS III.

Reactions in Which the Action of an Ordinary Oxidizing Agent is an Essential Feature.

The method used for third-class reactions employs, as the initial step, the resolution of the oxidizing agent into a number of simple oxides and the consequent amount of available or active oxygen.

The various oxides and the active oxygen are then used to bring about the results required by the general statement of the given reaction.

Example 1.

$$aFeSO_4 + bH_2SO_4 + cHNO_3 + aq. = dFe_2\,(SO_4)_3 + eNO + fH_2O + aq.$$

Proceeding in the manner mentioned and using the dualistic formula for the oxidizing agent, the various steps will be:

(1) $H_2O{\cdot}N_2O_3 = H_2O + 2\,NO + (3\,O)$

(2) $H_2SO_4 + (O) = H_2O + (SO_4)$

(3) $2\,FeSO_4 + (SO_4) = Fe_2(SO_4)_3$

Now the second and third equations must each be multiplied throughout by three in order to use the total amount of available oxygen and thus make it possible to eliminate it together with the other intermediate substance, (SO_4). These steps will then become:

(2′) $3\,H_2SO + (3\,O) = 3\,H_2O + (3\,SO_4)$

(3′) $6\,FeSO_4 + (3\,SO_4) = 3\,Fe_2\,(SO_4)_3$

The sum of (1), (2′) and (3′) will be the desired form.

$$6\,FeSO_4 + 3\,H_2SO_4 + 2\,HNO_3 + aq. = 3\,Fe_2\,(SO_4)_3 + 2\,NO + 4\,H_2O + aq.$$

Example 2.

$$aKMnO_4 + bNa_2C_2O_4 + cH_2SO_4 + aq. = dK_2SO_4 + eNa_2SO_4 + fMnSO_4 + gH_2O + hCO_2 + aq.$$

The oxidizing agent is decomposed into the oxides that are needed to make the final products and the residual amount of active oxygen.

(1) $K_2O{\cdot}Mn_2O_7 = (K_2O) + (2\,MnO) + (5\,O)$

Then the oxidizable substance is resolved in such a manner as to show what portion is to use the available oxygen of the preceding step.

(2) $Na_2C_2O_4 = (Na_2O) + CO_2 + (CO)$

The other steps will be:

(3) $(CO) + (O) = CO_2$

(4) $(K_2O) + H_2SO_4 = K_2SO_4 + H_2O$

(5) $(Na_2O) + H_2SO_4 = Na_2SO_4 + H_2O$

and

(6) $(MnO) + H_2SO_4 = MnSO_4 + H_2O$

These equations must be adjusted so as to permit the cancellation of equivalent quantities of the intermediate substances. The complete series, when adjusted, will be:

(1) $K_2O{\cdot}Mn_2O_7 = (K_2O) + (2MnO) + 5O$

(2′) $5\,Na_2C_2O_4 = (5\,Na_2O) + 5\,CO_2 + (5\,CO)$

(3′) $(5\,CO) + (5\,O) = 5\,CO_2$

(4) $(K_2O) + H_2SO_4 = K_2SO_4 + H_2O$

(5′) $(5\,Na_2O) + 5\,H_2SO_4 = 5\,Na_2SO_4 + 5\,H_2O$

(6′) $(2\,MnO) + 2\,H_2SO_4 = 2\,MnSO_4 + 2\,H_2O$

The sum of these equations will give the final balanced form.

$$2\,KMnO_4 + 5\,Na_2C_2O_4 + 8\,H_2SO_4 + aq. = K_2SO_4 + 5\,Na_2SO_4 + 2\,MnSO_4 + 8\,H_2O + 10\,CO_2 + aq.$$

CLASS IV.

Reactions Involving Combinations of Some of the Preceding Cases and Also Those Reactions That Cannot be Referred to Any of the Preceding Groups.

The methods used for fourth-class reactions will be combinations of the schemes employed in those classes to which the given compound reaction may be referred; or else they will be special methods that must be developed for those cases that cannot be referred to any of the preceding classes.

Example 1.

$$aKCl + bH_2SO_4 + cMnO_2 = dKHSO_4 + eCl + fH_2O + gMnSO_4.$$

This case is obviously a combination of a second and third-class reaction. And a combination of second and third-class procedures will give the desired result.

(1) $H_2SO_4 + KCl = KHSO_4 + (HCl)$

(2) $MnO_2 = (MnO) + (O)$

(3) $(MnO) + H_2SO_4 = MnSO_4 + H_2O$

(4) $(2\,HCl) + (O) = 2\,Cl + H_2O$

(1′) $2\,H_2SO_4 + 2\,KCl = 2\,KHSO_4 + (2\,HCl)$

Then the sum of (2), (3), (4) and (1′) is the final balanced form.

$$3\,H_2SO_4 + 2\,KCl + MnO_2 = 2\,KHSO_4 + MnSO_4 + 2\,Cl + 2\,H_2O.$$

Example 2.

$$aKOH + bCl + aq. = cKClO_3 + dKCl + eH_2O + aq.$$

This is the typical fourth-class reaction requiring the development of a special procedure for its resolution. Potassium hypochlorite, KClO, will be taken as the intermediate product, since such a compound can actually be formed by a suitable control of the conditions.

(1) $2\,KOH + 2\,Cl = KCl + (KClO) + H_2O$

(2) $(3\,KClO) = KClO_3 + 2\,KCl$

(1) $6\,KOH + 6\,Cl = 3\,KCl + (3\,KClO) + 3\,H_2O$

The sum of (2) and (1′) will be the final balanced form,

$$6\,KOH + 6\,Cl + aq. = KClO_3 + 5\,KCl + 3\,H_2O + aq.$$

Other Methods.

Another method that may be used for balancing equations is the one devised by Prof. O. C. Johnson and which is fully explained in the sixth edition of Prescott and Johnson's Qualitative Chemical Analysis on page 238.

Still another method that may be used in many cases is the algebraic method. The procedures will be illustrated by an example.

Example 1.

$$aHNO_3 + bCu + aq. = cCu(NO_3)_2 + dNO + eH_2O + aq.$$

This statement involves four different kinds of elements and five unknown coefficients. Still it is possible to arrange a series of independent algebraic equations and obtain values for the coefficients. On the basis of the different elements present the following equations can be written:

(H) $a = 2e$

(N) $a = 2c + d$

(O) $3a = 6c + d + e$

(Cu) $b = c$

Then by suitable transformations, values for each unknown in terms of some particular one can be evolved. The following are the secondary equations in terms of c:

$$a = 8/3\,c,\ b = c,\ c = c,\ d = 2/3\,c,\ e = 4/3\,c.$$

Then, by making $c = 3$, to eliminate fractional values, the coefficients for the reaction equation will be: $a = 8$; $b = 3$; $c = 3$; $d = 2$ and $e = 4$. The final form will be:

$$8\,HNO_3 + 3\,Cu + aq. = 3\,Cu\,(NO_3)_2 + 2\,NO + 4\,H_2O + aq.$$

Michigan College of Mines,
Houghton, Mich.

New York Section American Institute of Mining Engineers.—On February 13 Mr. Robert E. Cranston will present a paper on the design and mechanical features of the California gold dredge.

A Method for Measuring the Compressive Strength of Alloys

By J. R. HUBER.

The resistance of alloys to compression and methods for determining this important property are subjects which are conspicuous by their absence from the columns of our scientific literature. This is largely due to the fact that the different alloys vary widely in their behavior under compression. Some of them will break before showing any distortion, others will bulge or bend before breaking, and still others, like lead, will flatten out into a thin sheet and show no tendency to rupture. Owing to this variation it is exceedingly difficult to adopt a unit of measurement and a standard shape of test specimen which would be applicable in all cases.

The situation is very well summed up by Kent as follows: "For future experiments on crushing strength three things are desirable: First, an arbitrary standard shape and size of test specimen for comparison of all materials. Secondly, a standard limit of compression for ductile materials which shall be considered equivalent to fracture in brittle materials. Thirdly, an accurate knowledge of the relation of the crushing strength of a specimen of standard shape and size to the crushing strength of specimens of all other shapes and sizes. The latter can only be secured by a very extensive and accurate series of experiments upon all kinds of materials, and on specimens of a great number of different shapes and sizes."

The following method was worked out in this laboratory in connection with some research work on the white metal alloys, and proved very satisfactory. A cylindrical test piece was adopted owing to the ease with which it could be accurately machined in a lathe, as compared with the difficulty and expense of machining an accurate cube. The test pieces were 1 in. long and 1.128 in. in diameter, giving a cross-section having an area of 1 sq. in. A 50,000-lb. latest type, Olsen testing machine was used. The micrometer head was a 1-in. Brown & Sharpe, graduated to ten thousandths. The end of the micrometer head holder was threaded to fit the upper test bar holder of the machine. The lower one was removed and the 1 by 6-in. iron disk, which is supplied with the machine, was fastened in its place. The top of the bolt which holds this disk was rounded off to form a smooth spot upon which to screw the micrometer down. The cylindrical test piece was placed between two hardened steel disks 1-in. thick and 4 in. in diameter, which were obtained for the purpose. These were placed in the center of the base of the machine and the table lowered until the iron disk pressed upon the upper steel disk.

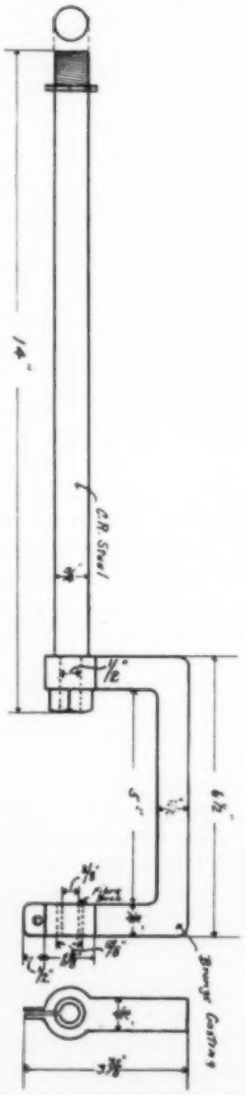


FIG. 1. — MICROMETER HEAD HOLDER.

In making the test an initial load of about 200 lb. was applied to accurately seat the specimen. The machine was turned backward by hand very carefully until the beam just balanced. The micrometer was then screwed down by means of the ratchet top and a zero reading taken. In the case of the softer alloys and where only the lower end of the curve was explored the machine was turned by hand throughout the test. The load was applied in increments of 200 lb. and a reading taken after each additional load.

With the harder alloys, where larger increments were applied

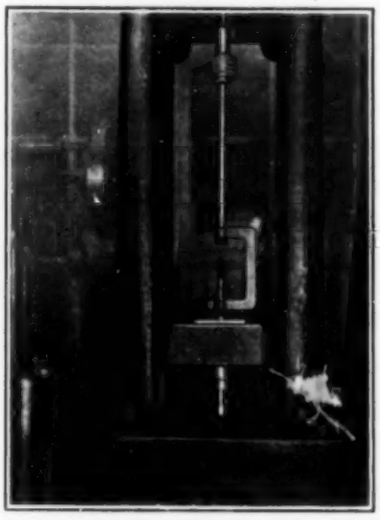


FIG. 2.—APPARATUS FOR MEASURING COMPRESSION STRENGTH OF ALLOYS.

and the whole capacity of the machine used, it was found practicable to run the machine with power and use the slowest speed.

The curves obtained from these tests indicated the behavior of the specimen under a steadily applied and increasing load, but the permanent set at each point was not obtained. This would probably vary with the elasticity of the alloy.

Although this method is not offered as a solution of the problem of compressive strength measurements it gave some very accurate comparative data on a series of non-ferrous alloys.

Lumen Bearing Co., Buffalo, N. Y.

The Wislicenus Smokestack for Fume Dilution was described in our December, 1911, issue (Vol. IX, p. 606), the essential feature being the construction of the upper part of the stack in lattice form. The American rights have been acquired by the Metallurgical Company of America, 52 Broadway, New York.

Shortage of water is a serious hindrance to good concentration work, and frequently means must be adopted to conserve the tailing water. The Frontenac mill, Black Hawk, Col., has recently added to its equipment a series of settling tanks for this purpose. The tailings from all machines are elevated to the settler, which consists of a series of boxes with hopper bottoms sloping to a central discharge spigot. The spigots are adjusted to allow thickened tailing to run to waste, while the water overflows from one box to the next, traveling 60 ft. before being drawn back to the mill system. This arrangement is expected to overcome the difficulties arising from muddy creek water, which, at certain times of the year, is insufficient for the demands of the mill.

Alunite is a newly discovered source of potash in the United States The largest occurrence is near Marysvale, Utah, and the deposit is of such importance that the U. S. Geological Survey has just issued a special *Bulletin*, No. 511, dealing with this particular deposit, and with alunite in general.

The Thermal Insulation of Furnace Walls.

BY CARL HERING.

The loss of heat through the walls of electric furnaces is of considerable importance because the heat is generally much more expensive than fuel heat and because these losses are by no means small. In cases in which the material is merely kept at a constant temperature, like in steel refining, this loss through the walls may even constitute the major part, and in fact sometimes nearly the entire input of power required. Moreover, often it is the cost of the power which is the criterion as to whether or not an electric furnace is to be adopted.

It is, therefore, often of importance for the engineer to be able to predetermine the best wall dimensions by calculating the loss for each of various alternative designs. Such calculations of the flow of heat through bodies, and deductions from them are perhaps not made as freely and as often as they should be, partly probably because they are considered to be tedious, and partly because they may not be generally understood. When properly made, however, they are in fact so exceedingly simple that there is no good reason for not making them when necessary in working out designs and estimates. The main point lies in the proper choice of those units which will reduce the calculations to the simplest possible; it, therefore, involves a problem in what might be called the conservation of mental effort. The units generally used make the calculation far more tedious than they need be.

The writer has from time to time published articles, papers, and discussions pertaining to various phases of this subject; the object of the present article is to summarize briefly the salient features and conclusions in these scattered publications, combining them into a brief description of how, in the writer's opinion, such calculations had best be made, how the results are to be interpreted, and what the chief factors are which govern such insulation.

Thermal and Electric Currents.—A flow of heat through a body may in many respects be treated just like a flow of electricity, known as an electric current. It is always caused by a difference of temperature, just as an electric current is always due to a difference of potential; where no such difference exists there will be no flow. The greater the difference of temperature the greater the flow (other things remaining the same). Such a flow is opposed by a thermal resistance; the greater this resistance the less the flow.

Stable State.—A flow of heat differs from one of electricity in that it is slow, while the latter is practically instantaneous; hence thermal calculations generally refer to the so-called steady or stable state when the flow of heat has become constant, which means that every part of the conductor has acquired the highest temperature to which it will be raised by the flowing heat under the normal conditions of a continuous and steady flow, and that the flow has reached its minimum; in this way the slower speed of the flow of heat may be eliminated from consideration.

The importance of fully appreciating the significance of this stable state may be shown by a case in which the inside layer of a furnace wall is a good heat conductor, like magnesite brick, while the outside is made of a very good insulator like mineral wool. In such a case, when this stable state has been reached it follows that the temperature at the junction of the two layers will be nearly that of the interior of the furnace, and such a high temperature may destroy the mineral wool. The higher the insulation of the outside layer the higher will be the temperature at this junction. When this stable state has been reached, the heat flowing from the hot charge has reached its minimum. It is like filling a thick, dry, porous cup with water; at first a large amount of water is absorbed by the walls of the cup, then it becomes less and less until a stable state of flow through the walls is reached.

Over Insulation.—With very high outside insulation it may happen that the temperature of the inside layer becomes higher than it can stand without softening, thereby collapsing, as for instance in the case of an arched roof. Such a case may be termed over insulation, and this has no doubt often been the cause of failure of inner parts of walls. For exceedingly high temperatures, as, for instance, in arc furnaces, it may therefore be absolutely necessary to permit a considerable flow in order to reduce the temperature of the bricks sufficiently, for wherever there is a flow there must be a lowering of the temperature.

No Perfect Insulator.—A thermal flow also differs from a flow of electricity in that such a thing as a practically perfect heat insulator does not exist; a vacuum is an exception, but as its use is impractical except for Dewar flasks, known popularly as thermos bottles, or in the laboratory, it may here be neglected; moreover, it is no insulator of radiant heat, as we get such heat from the sun through a vacuum; but with this we are not now concerned, as we are considering only the conduction of heat through walls. The absence of anything even approaching a perfect heat insulator means that some heat will always flow and that it cannot be confined to a conductor but will flow in any and all directions where lower temperatures exist.

Virtually Perfect Insulation.—The only way known to keep heat from flowing out through the sides of a conductor, that is, to compel it to flow in at one end of a conductor and out at the other, is to surround that conductor with a material which at each point has the same temperature as that of the adjacent point of the conductor. This is approximately the case with every cone-shaped, radial element into which a furnace wall may be assumed to be divided; in such elements the flow may therefore be assumed to be constant (in amount, not in density) through every cross section, like a cone-shaped electrical conductor; hence the quantity of heat which flows out of the cold end is equal to that which enters the hot end (assuming, of course, that the stable state has been reached); this is assumed to be the case in all that follows.

Units; Watts.—In calculations of electrical furnaces by far the simplest and most rational unit of flow of heat is the watt; this is also easily reduced to the kilowatt. The writer pointed out some years ago that this was a strictly correct measure of a thermal flow. Hence the older unit, calories (large and small) and thermal units per second, should be abandoned in electric furnace calculations. It is best to reduce all the necessary physical constants in tables once for all to watts. Gram calories per second $\times$ 4.18617 = watts; and watts $\times$ 0.238882 = gram calories per second. For further reduction factors see the writer's Conversion Tables.

Centigrade Scale.—The best temperature unit is, of course, the centigrade degree; partly because tables and data in all the best modern, up-to-date books are in that unit, and partly because it is the duty of every progressive engineer to do what he can to rid our calculations of such an irrational, awkward, senseless and cumbersome measure as the Fahrenheit scale. Moreover, in heat flow calculations the temperature difference should be stated as one number (just as in electrical calculations a potential difference is always stated as a voltage), not in the awkward and clumsy form "T-t" so common in the older text books. The highest of these two temperatures is always given elsewhere in a problem, hence is known. To reduce a drop of temperature in Fahrenheit degrees (not the temperature reading itself) to the drop in centigrade degrees, multiply by 5/9.

Resistance, not Conductance.—For furnace wall calculations, the successive layers of insulation are in series, hence it is far simpler[1] to use thermal resistances and resistivities (specific resistances) instead of conductances and conductivities (specific conductances) as usually used in the older text books. This will save an immense amount of tedious calcula-

[1]This journal, Vol. VII., 1909, p. 11.

tions with reciprocals. It also enables the temperature at the junctions of different layers to be readily determined. Moreover, like in electrical calculations, it is often much simpler to calculate resistances by themselves as such and not always have to calculate the heat flow also, as was formerly customary.

Thermal Ohm.—By far the simplest unit to use for thermal resistances, is a new one suggested by the writer, and not yet found in text books; the name given it is the thermal ohm.[2] The reason for using this new unit is that it greatly reduces and simplifies calculations, the unit being chosen to eliminate troublesome numerical coefficients or conversion factors, as will be shown below. It is also hoped that it will lead to uniformity in stating such data hereafter.

A thermal ohm is that thermal resistance through which 1 watt will flow when the difference in temperature is 1° C.

Tables of physical constants in text books usually give this physical property in terms of a thermal conductivity, instead of a resistivity, and often in terms of calories per second, though sometimes also in B.t.u., there being altogether about six or eight different units in use. The electric furnace engineer will find it greatly to his advantage to reduce all such data once for all to thermal ohms, thereby saving himself many subsequent tedious calculations; such a table was published in the December issue of this journal, p. 653. "Calories per second" and "B.t.u. per hour, minute or second" are thereby completely eliminated from all his calculations.

To reduce thermal conductivities given in terms of gram calories per second for 1° C. and a centimeter or inch cube, to specific resistances in thermal ohms, multiply the reciprocal of that number by 0.238882. Thus the thermal conductivity of fine grained quartz sand is given in the tables as 0.000131, meaning that so many gram calories of heat will flow through each square centimeter of a plate 1 cm thick, when the difference of temperature between the two faces is 1° C. The thermal resistivity will therefore be $0.2389 \times 1/0.000131 = 1820$. thermal ohms, for a centimeter cube. To reduce this to 1-in. cube multiply by 0.3937 or use 0.0940478 instead of 0.238882 in the first reduction. To reduce conductivity units in B.t.u. (pound-Fahr. units) per hour, per square foot, per inch thickness, per degree Fahrenheit, to thermal ohms, inch cube units, multiply the reciprocal by 273.013. For further conversion factors see the article on the thermal ohm cited above, and the writer's Conversion Tables.

The resistivity of the metals vary from about 0.25 to about 3 in thermal ohms for one centimeter cube; various furnace bricks from about 10 to 150; granular or fibrous materials, about 250 to 6000. The unit is therefore a convenient one to use in practice. It is, moreover, equal to 10^{-7} times the true absolute unit (not the so-called absolute unit based on the gram calorie), hence is a rational unit and is in decimal relation with the electrical units.

Thermal Ohm's Law.—When the above units are used, the calculation of flows of heat become the acme of simplicity; the law is then the exact duplicate of the electrician's favorite Ohm's law. If W is the flow of heat in watts, T the temperature drop in Centigrade degrees and R the thermal resistance in thermal ohms, then $W = T/R$. Therefore by using the thermal ohm all further reduction factors or coefficients disappear by becoming unity like in Ohm's law.

If, for instance, the drop of temperature between the inside and outside of a wall of an electric furnace is 1500° C. and the total resistance is 0.05 thermal ohms, the loss will be $1500/0.05 = 30$ kw. Or if the allowable loss is 30 kw the insulation resistance must be $1500/30{,}000 = 0.05$ thermal ohms.

Thermal Resistance of a Body.—The total thermal resistance of a given body, like a furnace wall or any part of it, is determined just like in electrical calculations. If r is the thermal resistivity (specific resistance) of the material in thermal ohms (obtained from tables), then the total resistance R of the particular body, in thermal ohms, is $R = rL/S$, in which L is the length and S the cross section. This, of course, applies equally well to inches as to centimeters, provided the same units are used consistently throughout. The thermal ohm as a unit is, of course, independent of any units of length or section; but with specific resistances (resistivities) one must specify whether they refer to the centimeter cube or the inch cube.

If, for instance, the mean thermal resistivity of fire brick is 30 thermal ohms in cu. in. units, then the resistance of a brick 8 x 4 x 2 in., taken between its two flat sides, will be $R = 30 \times 2/32 = 1.87$ thermal ohms.

Several Layers.—When a wall consists of several layers of different materials, the resistance of each layer is first calculated by itself, and as they are in series, they are then added to give the total resistance; from this total the flow is then calculated when the inside and outside temperatures are known. It would, of course, be incorrect to calculate the flow in each one separately, as the temperature drops in each are not a matter of choice, but are a consequence. However, if one wishes to arbitrarily fix the temperature at the junction of different layers, one can then determine what the resistance must be in order to produce that drop in each case, on the basis of an assumed flow. From this resistance one can then calculate what the length and section must be to give this amount of insulation resistance.

As an example, taking simple figures and omitting joints, mortar, etc., let it be decided to have a 4-in. layer of magnesite brick in the inside, then a layer of 12 in. of fire brick, and finally ¼ in. of sand between the brick and the casing; total 16¼ in. Assume the resistivity of the magnesite brick in thermal ohms to be 14 in inch units, fire brick 29, and sand 109 (the writer assumes no responsibility for these data, but they are probably approximately correct). In order to make the problem more general, assume a radial piece of the wall 1 sq. ft. in section at the inside wall surface, and for simplicity neglect the flare.

The resistance of the layer of magnesite brick then is $14 \times 4/144 = 0.39$ thermal ohm; of the fire brick $29 \times 12/144 = 2.42$; of the sand $109 \times .25/144 = 0.19$; total 3.0 thermal ohms. If the drop of temperature was then found in an actual case to be 1500° C., the loss through a square foot equals $1500°/3$ thermal ohms $= 500$ watts.

In this class of problems either the drop of temperature or the loss in watts must be known or assumed in order to determine the other.

Suppose the thickness of the outside layer of sand was left to be determined so that the outside temperature should not exceed 100°, when it is 1600° inside; and on the basis of an allowable loss of 500 watts per square foot of inner surface. The total resistance must be $1500/500 = 3$ thermal ohms; that of the magnesia and fire brick together is 2.81, leaving .19 to be supplied by the sand. The thickness is then found from the resistance formula to be $0.19 \times 144./109. = 0.25$ in.

Suppose as an alternative the fire brick be reduced by one course, hence is only 8 in., and that this course be replaced by 4 in. of sand on the outside; total 16 in. Then the resistances will be 0.39, 1.06 and 3.03, total 4.48 thermal ohms, which with the same drop of temperature 1500° gives 335 watts; hence with a slightly thinner wall and a cheaper material the loss is considerably less than before.

Temperatures at the Joints.—With the same simple formula the temperatures at the joints of such layers can readily be calculated if the inside temperature and the total drop are known. It may sometimes be necessary to calculate these temperatures in order to find whether the materials of each layer can stand them. In the first of the above examples the drop in the magnesite brick will be $T = WR = 500 \times 0.39 = 195°$. Hence if the inside temperature is 1600° that at the first joint

[2] This Journal, Vol. IX., January, 1911, p. 13. Also Jour. Frank Inst., Dec. 1911, p. 569.

will be $1600 - 195 = 1405°$ C. The questions of whether the fire brick will stand this or whether it will flux with the magnesite and run off, whether the magnesite will soften all the way back to its cooler side, hence lose its strength, etc., must then be considered. The drop through the fire brick will, by a similar calculation, be $500 \times 2.46 = 1230°$, hence the temperature at the sand is $1405 - 1230 = 175°$. The drop through the sand is 95°. Adding all these drops gives the total, 1500°, as nearly as can be expected from such abbreviated figures.

In the second example, with the thicker layer of sand, it will in this way be found that the fire brick junction with the magnesite is still higher, 1470°, because the heat flow is considerably less. Also that the hot side of the sand layer will now be 1120° C, the drop through the 4 inches of sand being now very great, namely 1010°. Knowing these temperatures the calculations should then be repeated with the resistivities for those temperatures.

Using conductivities as recommended in most text books instead of resistivities these extremely simply calculations would become very tedious; and using any other unit than the thermal ohm, they would be burdened with the incessant use of conversion factors besides considerably more mental effort in order not to make errors.

Flare of Walls.—The wall thickness in a well-insulated furnace being thick relatively to the inside, especially in smaller furnaces, it becomes necessary to consider the flare, as the outside layers have not the same insulating effect per inch of thickness on account of their larger cross-section perpendicular to the flow.

The rough-and-ready rule to take the simple arithmetic mean of the two end surfaces is only approximately correct and only when the flare is small; for relatively great flares, such as may exist in smaller furnaces, the error becomes quite great, and beyond a certain range, namely, at a thickness equal to about three-fourths the inside dimensions, it leads to the absurdity that the loss becomes greater with thicker walls. Hence it should not be used except for thin layers in which the flare is small.

For a spherical or a cubical furnace or any parts of the same, like one-half, the correct mean value is the square root of the product of the two surfaces, that is, their geometric mean. For other shapes approaching these this mean cannot be far wrong. For cylindrical furnaces the correct law is not so simple as it involves logarithmic functions, but as cylindrical furnaces are generally short and necessarily have large ends, it would probably be correct within the errors of other parts of the calculations to use the geometric mean in such a case also.

In some recent papers* the writer gave the rigidly correct formulas, and by applying them showed how rapidly the insulation value of the outer layers decreased as the thickness increased owing to this flare.

The curves in Fig. 1 are reproduced from one of these papers, but are here reduced to watts, thermal ohms and centigrade degrees; they are for spherical and cubical shapes, as these are the only two for which a single curve can be given for all sizes; for shapes approximating these the results would probably not be far wrong.

The vertical distances, after certain reductions, give the losses in watts per centigrade degree of drop in temperature when the horizontal distances represent the relative wall thicknesses. It will be seen how very rapidly the losses decrease at first for relatively thin walls, but as the thickness increases considerably the rate of decrease of the loss becomes quite slow, and as the volume of the insulation material per extra inch of thickness then increases quite rapidly, namely, as the square of the distance from the center, it becomes questionable whether the extra saving of the loss is justified by the expense. For reasonably thick walls it may be truly said that "bricks are cheaper than kilowatts," but a practical limit is reached, especially for tilting furnaces in which the additional size and weight become objectionable.

The curves are here drawn to scale so that the losses may be determined from them directly in watts thereby saving the tedious calculations of the geometric means. They are drawn

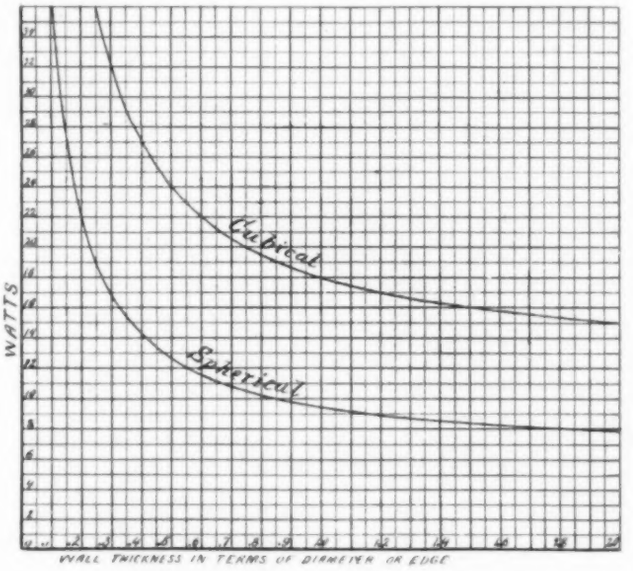


FIG. 1.—LOSSES IN CUBICAL AND SPHERICAL FURNACES.

for 1 inch or centimeter inside diameter of a sphere or the edge of a cube, and for a resistivity of one thermal ohm in inches or centimeters respectively. The horizontal distances give the wall thickness in terms of the diameter or edge; for instance, 1.2 on that scale means that the wall thickness is 1.2 times the inside diameter or edge, in either inches or centimeters. Hence by merely multiplying the watts given by these curves by the actual diameter in inches or centimeters and dividing by the actual resistivity in thermal ohms, in either inches or centimeters, the result will be the total loss for the whole furnace per degree drop of temperature. This need then merely be multiplied by the total temperature drop to get the total loss in watts.

For instance, if the inside diameter of a spherical furnace is 20 inches and the wall thickness 24 inches, then the thickness is 1.2 times the diameter; for 1.2 on the lower scale the watts are 8.9. Let the walls be of fire brick having a resistivity of, say, 30. Then $8.9 \times 20/30 = 5.93$ watts per degree, hence, for 1000° it will be 5.93 kilowatts.

This assumes that the whole of the inside surface is at the same temperature, hence that the heat is supplied to the inner surface as fast as it flows away. This is probably approximately true when the loss is relatively small per unit of surface, but when rather great there will probably be less heat loss per unit area above the level of the molten charge in a resistance furnace in which the heat is generated in the material, and more in this upper part than in the lower in arc and reverberatory furnaces in which the space above the charge is the hotter as the heat is generated there.

Under the assumption of uniform temperature over the inside surface, the following can be shown to be true for spherical or cubical furnaces, which are the only definite shapes for which such general rigidly correct laws can be made. It is also assumed herein that the resistivity of the materials is uniform throughout, which is not strictly correct, but some such assumptions of uniformity must be made or else no general laws could be established, and such laws are often valuable guides.

*Heat Conductances Through Walls of Furnaces. Hering, Trans. Amer. Electrochem. Soc., Vol. 14, 1908, p. 215. For a more detailed discussion of the correct formula for long cylinders see "Thickness of Electric and Thermal Insulation," Elec. World, Nov. 25, p. 1303.

For the *same actual loss* in furnaces of different inside dimensions, the wall thickness increases with very great rapidity as the inside size increases, in fact far too rapidly to make it practicable to maintain the loss the same for the larger furnaces. For instance, for four times the inner diameter the volume of insulation is about 2500 times as great. This does not mean that furnaces should not be made large, but merely that it is of very great importance not to make the inside dimension any larger than necessary to hold the charge. This applies more particularly to the hottest part, which is below the liquid level in resistance furnaces, and above it in arc furnaces.

For the *same relative loss*, that is, for the same per cent loss or the same loss per unit inside volume or pound of charge, just the reverse is true, that is, the thickness becomes impracticably great for the smaller sizes and relatively very small, becoming nearly constant for the larger ones. The volume of insulation in this case is even far greater for the smaller sizes. This shows the futility of trying to insulate a small furnace as well as a large one, except when a very large bulk is not objectionable, as in some laboratory furnaces. It also shows the great advantage of furnaces of large capacity over those for smaller ones, also the great importance of using one large furnace instead of several smaller ones, unless there are other considerations of more importance than these losses.

For the *same relative thickness* of wall the loss in spherical furnaces increases as the diameter. But the contents increase as the cube of the diameter, hence the loss per pound of charge decreases rapidly with increasing sizes.

Comparing a sphere with a cube whose edge is equal to the diameter of the sphere, both having the same wall thicknesses, the loss per unit of volume is the same; the cube, however, will have nearly twice the capacity. For the same capacity and the same relative wall thickness, the loss for the spherical one will be considerably less.

For cubical furnaces with the same relative wall thickness, the losses are proportional to the length of the edge, like with the spherical one.

All the above apply, of course, also to any fraction of a sphere or cube, like a half or to one of the sides of a cube.

For oblong, rectangular furnaces it will probably be sufficiently accurate to use the geometric mean of the inside and outside surfaces as the mean section.

For cylinders the losses are the same for all diameters when the relative thicknesses remain the same, but this applies only to long cylinders and does not include the ends, hence would not apply to short cylindrical electric furnaces.

If the inside diameter of a spherical furnace is d, the outside D and the thickness L, all in inches or centimeters, and if the resistivity is r in thermal ohms, then the total resistance in thermal ohms can be calculated from the formula $R = rL/(\pi Dd)$ which avoids the tedious square root calculation for obtaining the geometric mean, yet is rigidly correct.*

Similarly for a cube whose inside edge is d, the outside one D and the thickness L, the resistance $R = rL/(6Dd)$.

These modified formulas also show the general law that the resistance, hence the loss, will be the same in all different spherical furnaces when the product of the two diameters divided by their difference (namely, twice the wall thickness) is the same. This is true also of cubical furnaces in which the edges take the place of the diameters.

These formulas apply to the whole wall; for a hemisphere one-half is taken, and for one face of a cube one-sixth.

For further details concerning flaring walls see the original article cited above, from which this is taken.

Temperature Coefficient.—Little seems to be known about the temperature coefficients of the thermal resistances of insulators, but for high temperatures, such as in furnaces, even a small temperature coefficient makes quite an appreciable difference, and should therefore not be neglected. As a rule, the thermal resistance of heat insulators seems to become less as the temperature increases. The constants as usually given for low temperatures are therefore not reliable to use for high ones without some allowance. In tables these constants should therefore always be accompanied by the temperatures at which they were determined.

Nusselt,* who determined apparently very good values of the thermal conductivities of a number of thermal insulators (though, unfortunately, not of those usually used for the walls of high temperature furnaces), states that approximately the conductivity of such insulators increases $1/273$ of their value for each centigrade degree from 0°C.; this is approximately the same rate (though of different sign) as for the electrical resistivity of copper. If this law continues for high temperatures, then at 273° C. above 0° the conductance of a body would be doubled or the resistance halved; at about 1100° C. the resistance would be only one-fourth, and at about 1350° only one-fifth that at ordinary temperature. The importance of taking this into consideration is therefore evident.

When the mean resistivity of a material is given for both a small and a large range of temperature both from zero, or room temperatures, say from 0° to 500° and again from 0° to 1300°, it is possible to calculate definitely what the mean value will be between the two higher temperatures, from 500° to 1300° in this case, and without the assumption of any law of variation.** If t is the drop of temperature (hence not necessarily the temperature itself) for the small range, T that for the larger range, D the drop between the two high temperatures, for which the mean resistivity is desired (hence $1300 - 500 = 800°$ in this case); and if r is the mean resistivity for the smaller range, R for the larger one, and X for the high range D then

$$X = \frac{rRD}{rT - Rt}$$

It is correct for any units provided they are used consistently throughout.

Air Spaces Within Walls.—Ray and Kreisinger*** recently showed that an air space left between the two parts of a double wall for insulation purposes did not accomplish its object, as the effective resistance of this air space was less than if it had been filled with bricks.

A deduction made by the writer,† which would follow from the laws used by them, is that increasing such an air space would actually decrease the total resistance. The reason apparently is that on account of the greater air space the outside wall becomes larger, hence conducts better.

Joints.—Little seems to be known quantitatively about the resistance of a joint between two bricks, but it is known that with good conductors of heat like the metals even a very thin crack affords such a great resistance that the metal may be red hot on one side of it, while it is black on the other. It is likely therefore that the same thing is true, though possibly to a less extent, with heat insulators. Hence where bricks are not cemented together with mortar to form practically one solid mass, the joints are likely to offer very appreciable insulation resistances, and if so, they are the cheapest kind of insulation, involving also no weight or space. The writer recently constructed a furnace in which the bricks were all laid parallel to the outer sides, thus making as many joints as possible perpendicular to the flow and the iron casing on the outside of this furnace became only slightly warm to the touch. Most of the bricks were of a particularly porous kind and very light in weight.

*This formula is a good illustration of how an equation, which has not been reduced to its simplest terms (as L is half of D-d, hence could be eliminated) is really simpler to use arithmetically than the reduced form.

*Nusselt. Zeit. Ver. Duet. Eng., June, 1908, p. 906.
**This journal, Feb., 1909, p. 72, where the formula is deduced for conductivities instead of resistivities.
***Bureau of Mines, Bulletin No. 8.
†This journal, Sept., 1911, p. 438.

Actual Losses Through Walls.—The writer found that the leakage of heat through the walls of two presumably well-built commercial furnaces was roughly about 1 kw. per square foot of surface of the molten charge, assuming this rate to be about the same from the top surfaces as through the walls. This figure was obtained from experimental data of two induction furnaces of entirely different sizes and manufacture* by measuring the input of energy over night while the furnaces were merely kept hot (presumably above the melting temperature of steel) which input, therefore, represented the continuous losses. The figures for the two different furnaces agreed remarkably closely, which was in part no doubt accidental. The individual figures were both a little higher, and presumably at the working temperatures the loss would be somewhat higher still. But, on the other hand, in a furnace which is not restricted in its insulation in both thickness and rigidity, as an induction furnace necessarily is, the insulation could no doubt be improved so as to reduce this figure, and for this reason it is believed that 1 kw. per square foot is a safe rough-and-ready figure to use.

This will give a good general idea of the magnitude of these thermal leakages through walls. If published figures of the thermal conductivities of various refractory bricks are correct, and if numerous joints can be introduced as in the brick work of the usual furnaces, it would seem to be possible to reduce this possibly to a half or even less. It should, therefore, be used merely as a very crude figure.

Shape.—It is evident that the loss of heat from a charge must all take place through the sides, bottom and top of the charge, that is, through its bounding surfaces. Hence it would be reduced to a minimum when the charge is in the shape of a sphere, which has the least surface for a given volume. As this is impracticable, an approach to it in practice is to make the hearth a hemisphere.

Hence to reduce the losses of heat from the charge to the least practical, the shape of the hearth should be as near as practical to a hemisphere. As a loss of about 1 kw. per square foot is by no means small, it seems to be important to approach this shape as closely as other practical considerations permit, such; a bath, for instance, would be rather deep, and it might be difficult to get the heat of an arc over the top to flow down to the bottom, which it can do only by slow conduction and possibly some convection.

In a recent article** the writer showed the very great possible economies which might be gained by this one feature of shape alone, especially in such furnaces as those for steel refining in which the chief purpose is to keep the metal at its high temperature. The results showed that for a 10-ton furnace these stand-by losses might in this way be reduced to about 9.5 kw. per ton, even on the basis of a little over 1 kw. per square foot, and to half of this if the insulation could be doubled. At 1 cent per kw-hour the cost of this energy would be only about 10 cents per ton per hour, which is certainly not great.

Heat Emission from Surfaces.—When heat flows out through an insulating wall it meets with some resistance when it passes from the outside surface to the air. For high densities of the heat flow this resistance may be quite great. It is this surface resistance which in part determines what temperature the outside of the furnace will assume when the heat leakage flows out and it will also in part determine the amount of leakage.

Our knowledge of these skin resistances, if they may be so called, is somewhat meager, especially of the laws governing their values. But even if we did know the laws, the actual conditions may be so different from the theoretical ones that the results might be very different from those found by calculation. For this reason it seems best, until better information exists, not to attempt any theoretical calculations but to be guided by actual experimental results.

For this purpose the writer has compiled tables reduced from values gathered from various sources, giving the amounts of heat flowing across such surfaces and the existing temperatures.* The heat flows are there reduced to watts, the temperatures to centigrade degrees and the skin resistances to thermal ohms; the figures are, therefore, directly applicable to electric furnace calculations.

As far as concerns the outside walls of furnaces, they show the following, which, however, must be understood to be rather crude data, as the results from different sources did not always agree well.

When about one-half a watt per square inch flows into the air from ordinary iron surfaces the temperature will be quite warm to the touch. With about 1 watt it would probably sizzle when wetted. With roughly half a kilowatt per square foot it would be very hot to the touch. At a dull red heat it would probably be losing about 7 to 11 kw. per square foot. Bright red hot surfaces of metal are probably losing about 12 to 15 kw. per square foot, but in a still atmosphere like in the inside of a covered resistance furnace, the loss may be only about 4½ to 8.

It will be found from these figures that in well-insulated furnace walls the loss is governed chiefly by the insulation itself and very little by the outside contact resistance, hence the latter need not be given much concern. In other words, all the heat which will leak through the insulation in such furnaces will find its way easily to the air without involving any very high temperatures there.

These surface resistances are, however, of great importance in steam boilers or other structures in which the thermal resistance should be as low as possible instead of as high as possible.

These skin resistances can also be expressed in thermal ohms, and are then merely added to the resistances of the walls. The heat flow will then be equal to the total temperature drop (to the air in this case) divided by this total resistance. But as these skin resistances seem to be of little importance in determining the total leakage in well-insulated walls, it seems unimportant to make more refined calculations for apparatus which is as crude as an electric furnace necessarily is, and in which other governing factors are so variable and the physical constants so inaccurately known.

On ordinary iron surfaces the skin resistance for temperatures of about 60° to 200° C. seems to be about 100 thermal ohms per square inch, hence about 0.7 per square foot, which may be added to the insulation resistance to give the total.

For small laboratory furnaces it might be found worth while to polish the outside, as it seems that a polished surface has a much higher thermal resistance; it is alleged to be about five times that of a rough surface. It will then get hotter and one must not be deceived into thinking that therefore the loss is greater for it is really less. But with a good wall insulation it will probably not make much difference whether this relatively small skin resistance is or is not five times as great. The same effect obtained by a polish may be produced with a thin layer of fibrous or granular material which has a very high thermal resistance. This, however, adds to the thickness.

Outside Temperature.—The question of what relation, if any, the temperature of the outside of a wall bears to the total loss is a somewhat complicated one and has been discussed at considerable length. An analysis of it will be found in an article by the writer in this journal, April, 1911, p. 189, one of the conclusions in which is confirmed by the tabulated results mentioned above, namely, that the skin resistance has but little effect. Another is that for the *same furnace* the loss is least the hotter the outside wall, because the temperature drop through the fixed resistance is then the least, hence $W = T/R$ is then least. It would be a grave mistake, however, to compare different furnaces in this way. If a furnace gets hot on

*This journal, November, p. 590.
**This journal, November, p. 593.

*Flow of Heat Through Contact Surfaces. This Journal, January, 1912, p. 40.

the outside, the probabilities are that by reconstructing it so that it will be cooler the loss will be reduced. The safest general conclusion is not to be misled by the outside temperatures of different furnaces, a hot one might be a better insulated one than a cold one, but, on the other hand, if it is hot it is likely that it can be improved still more and be made cooler.

Vacuum Pans with Jackets.

By B. Viola.

Member American Society of Mechanical Engineers.

In certain cases for special liquors the vacuum pans are sometimes heated not by means of heating coils, but double bottoms or jackets are provided for this purpose. The results obtained from an evaporator or vacuum pan by this construction are entirely different from those considered in former articles, because the heating steam does not have the same

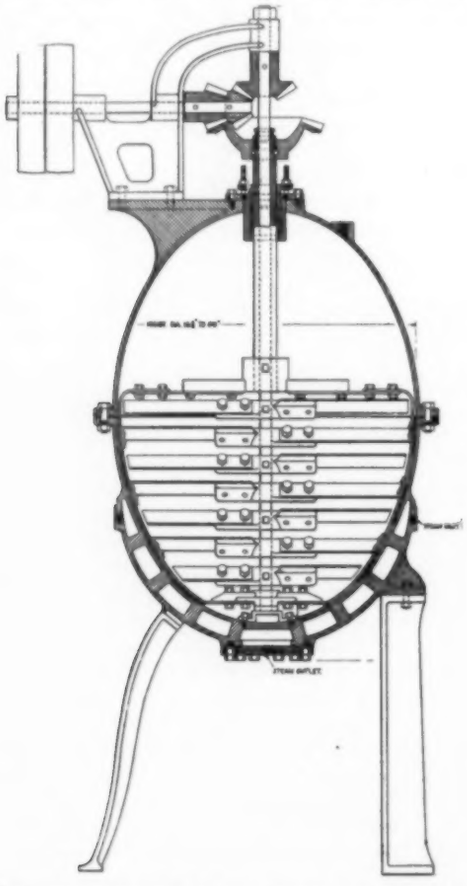


FIG. 58.—CROSS-SECTION OF A CAST-IRON JACKET VACUUM PAN.

uniform effect on all parts of the heating surfaces. The steam does not pass equally over the heating surface with the same compulsory effect; entering at the inlet, the steam spreads in the whole jacket and tries to escape by the shortest way through the outlet. Naturally, therefore, the heating surface does not give the same results as in the case of heating coils or tubes. This is the reason why the heat transmission coefficient on which our former calculations were based (see the article in the January issue) cannot be used in these cases, since it varies too much. The larger the jacket the smaller will be the value of the coefficient. Scales found on the heating surface have also to be taken into consideration.

The efficiency will certainly be the higher the more steam inlets are provided. The evaporative capacity also depends largely on the temperature of the steam, there being, of course, no strict proportionality. Further, with an increase in the temperature of the boiling liquid the heat transmission increases.

Moreover, the steam always carries a certain quantity of air, which prevents its close contact with the heating surface; this has also to be taken into consideration. This air then escapes through the exhaust line, which always has to be placed in the lowest point of the jacket.

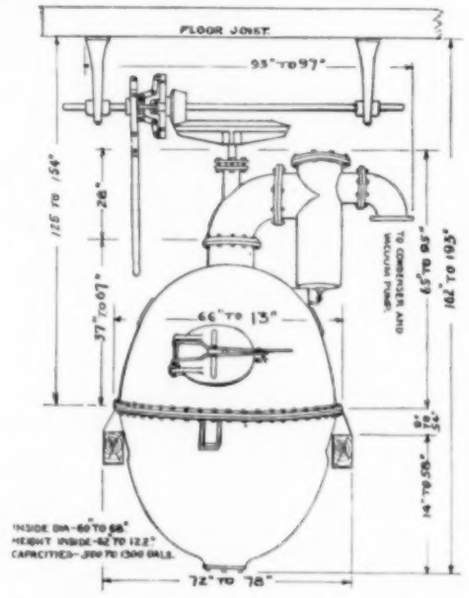


FIG. 59.—CAST-IRON JACKET VACUUM PAN WITH JUICE CATCHER.

In general the transmission of heat by a copper double bottom can be expressed, by using the formula 1 from our previous article (January issue, page 31), in the form:

$K_c = 1400$ to 1800 C calories per square meter an hour; the smaller the diameter, the larger is K_c and vice versa.

The incrustation of the heating surfaces alters considerably

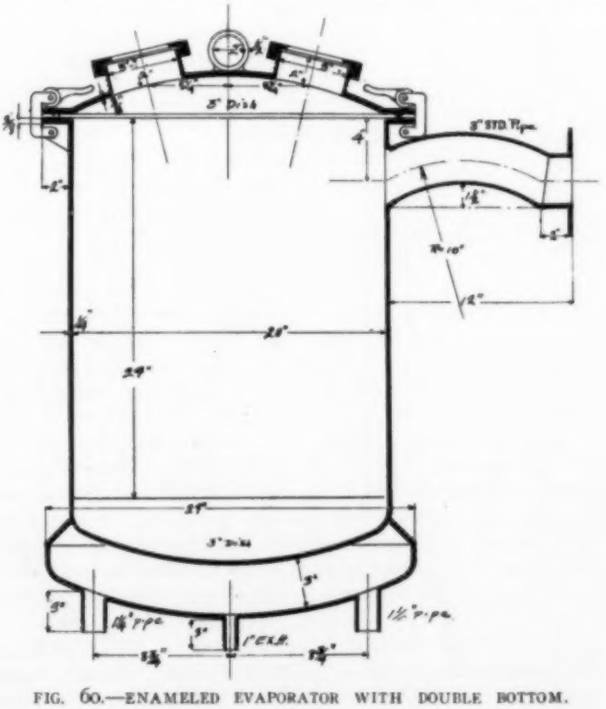


FIG. 60.—ENAMELED EVAPORATOR WITH DOUBLE BOTTOM.

the value of the heat transmission and our former formula (2) for the heat Q may be changed as follows:

$$Q = \frac{HC}{2}(t_2 - t_1)$$ calories per hour for a double bottom of copper, where

H = heating surface in square meters.

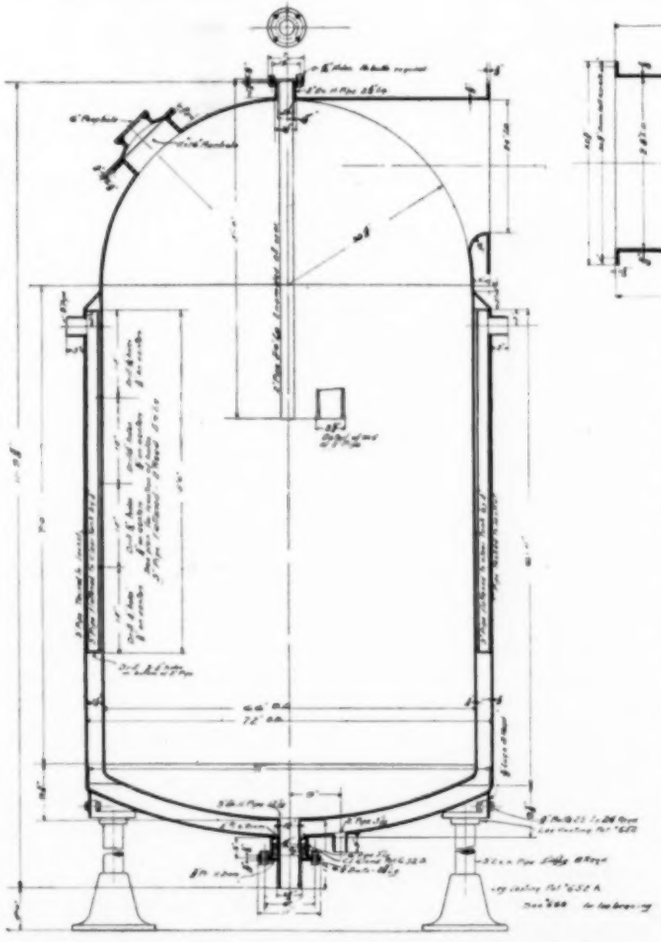
C = heat transmission coefficient in calories per square meter per hour.

t_2 = temperature of heating steam.

t_1 = temperature of boiling liquid.

To give the results in a more practical form we may say that copper-jacketed kettles will evaporate at the same steam pressure about 4 to 2.5 gal. per hour and square foot, while the diameter varies between 1.5 to 10 ft.

Cast-iron vacuum pans of the Dopp system are shown in Fig. 58 in cross-section and in Fig. 59 in perspective view equipped with pulley drive and with juice catcher and friction clutch drive respectively.



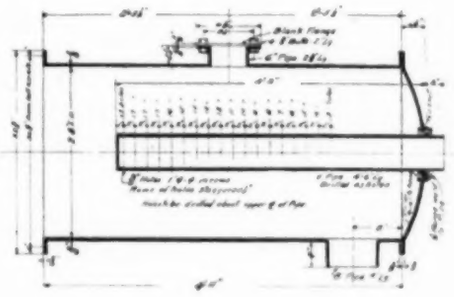


FIG. 61.—ENAMELED JACKET VACUUM PAN EQUIPPED WITH JET CONDENSER.

It may be stated here that these vacuum pans are also equipped with double-motion agitators and Fig. 58 shows this type of construction, used in sizes ranging from 10 to 500 gal. The outlet is not shown in the drawing, as this is furnished in different styles, according to the different kinds of work they are to handle.

The bottom of this pan is made up of a seamless steam-jacketed kettle which is cast by a special process, rendering them absolutely smooth and free from the possibility of leaky rivets, stay-bolts or joints.

The shells are reinforced by stay-bolts, these stay-bolts being cast at the same time as the shells.

Fig. 59 shows the same type of vacuum pan for a total capacity of from 600 gal. to 1300 gal., equipped with a single-motion drive.

The following results were obtained with the above mentioned Dopp cast-iron vacuum pans of 300 gal., with a heating surface of 17.34 sq. ft.:

Feed at temperature of vacuum.

Vacuum.	Steam pressure in jacket.	
	80 lb.	120 lb.
24 in.	44.37 gal.	51.59 gal.
26 in.	49.50 gal.	56.89 gal.

Feed at temperature of 60 deg. Fahr.

Vacuum.	Steam pressure in jacket.	
	80 lb.	120 lb.
24 in.	41.11 gal.	47.8 gal.
26 in.	46.67 gal.	53.6 gal.

The number of square feet of heating surfaces in these various pans ranges from 1.695 in the 10-gal. pan to 55 in the 1000 or 1300-gal. pan. In the 300-gal. pan it is 17.34 sq. ft.

For the evaporation of certain acids or milk, the so-called vitreous-enameled steel vacuum pans can also be used satisfactorily.

This enamel does not contain metallic oxides, such as those of lead, tin, arsenic, etc., since in its chemical composition it is practically all quartz. This makes it not only acid-proof, but absolutely non-poisonous, so as to meet the strictest requirements of the pure food laws of all governments. This vitreous enamel has all the chemical-resisting qualities of plate glass, but does not have its fragile qualities; it is actually fused into the steel at a temperature of about 3000 deg. Fehr., so that there is absolutely no danger of cracking, crazing or scaling due to expansion or contraction from alternate heating or cooling.

Further below I am showing the types which are mostly used in the evaporation of milk products and certain acids.

Fig. 60 shows a small enameled steel vacuum pan with double bottom and two steam inlets and one exhaust outlet in the center of the bottom.

Below the cover there is provided the neck-connection to the condenser.

For emptying this vacuum pan the top cover is removed, which also contains two peep holes.

Fig. 61 shows an enameled vacuum pan with double bottom and side jacket. In connection with the two side steam inlets, another inner pipe can be seen, which is provided for the purpose of protecting the inside kettle from impact of the steam. This arrangement has proved very satisfactory in practice. This also helps distribute the steam at the bottom of the tank and to cause a much better circulation.

On the upper right-hand side there is a horizontal pipe with an inner pipe of much smaller diameter in the center. It is connected with the vapor outlet on the top of this vacuum pan. It serves as a condenser for the escaping vapors, cold water entering the center-pipe, which is perforated on the top and works as a jet condenser.

Fig. 62 is another type of a vitreous enameled jacketed vacuum pan.

It is provided with all the necessary openings needed for the control of the evaporation of the liquor.

Fig. 63 is the same vacuum pan connected with an enameled juice-catcher (the author's construction).

The evaporative capacities of these enameled vacuum pans are proportional to the heat transmission capacities of the material of which they are made as compared with copper. These data were mentioned in some of the previous articles. I may refer here only to Fig. 49 in my article in the issue of July, 1911, of this journal (Vol. IX, page 354), showing a homogeneous lead-lined jacket evaporator, figures of its capacity being given on page 352.

Calculation of Furnace Charges--II.

BY REGIS CHAUVENET.

In considering analytical data from which slags and mattes are to be computed regard must be had to the questions: which of the elements are presumably reducible to metal,

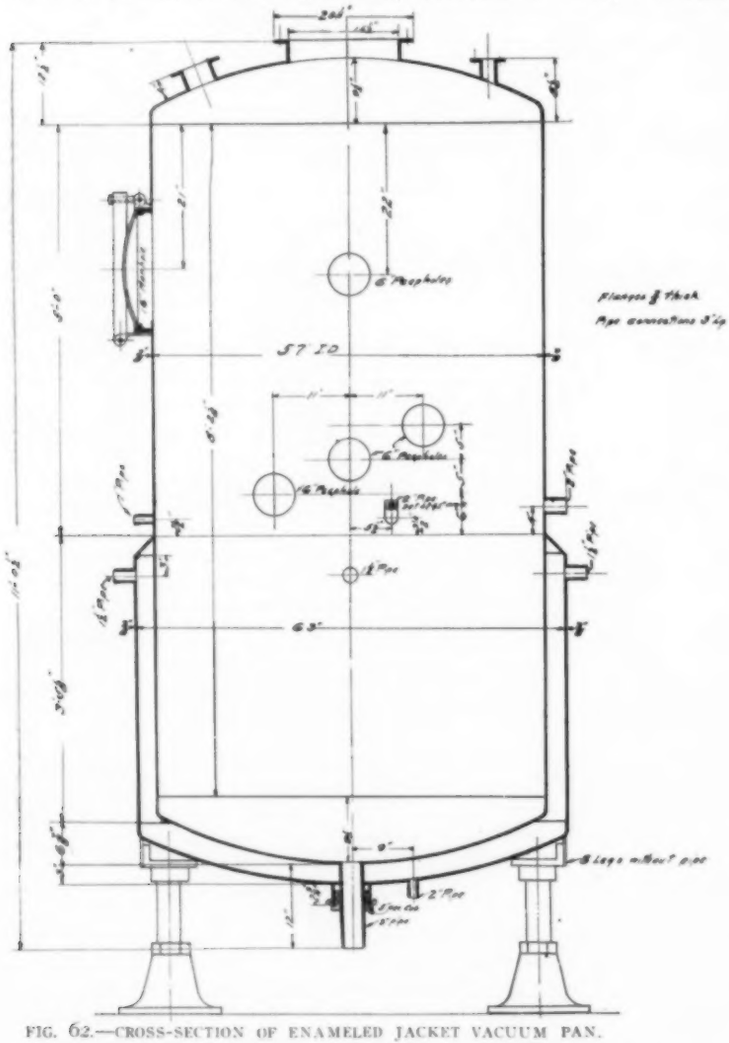


FIG. 62.—CROSS-SECTION OF ENAMELED JACKET VACUUM PAN.

which are volatile, whether as gases or as "fumes", which will enter the matte, and finally, which will combine to form the "slag," whether of themselves or by combination with other materials, added for the purpose, which may be grouped under the broad term of "fluxes." Frequently the flux carries "values" also, but this is a feature which we propose to omit in the present treatment of the topic.

We shall describe the various requirements, in a theoretical sense, of slags, then show how to "take out" the matte, next how to adjust the bases so as to simplify the calculation, and finally, before proceeding with the actual calculation of charges based on analyses of materials, we shall give a few types of slags (analytical) for iron, copper and lead furnaces.

Formulistic and Percentage Slags.

We may take up (a) "formulistic" slags, in which the requirement is that its composition shall show a definite chemical formula, and (b) "percentage" slags, whose requirement is simply as to percentage of certain elements, frequently limited to percentage of silica only.

In the Chemical Introduction, however, we have already shown that any formula may be quickly transformed into an analytical statement. Later, in setting forth the method recommended as the most general for all slag computations, we instruct the computer to start his computations by putting his required "formula," if he is to figure on that principle, into the percentage shape before proceeding.

We may subdivide formulistic slags again, roughly, into two classes. The first of these we call true formulas, viz.: Not only is the silica properly adjudicated to each base, but the bases themselves are in a definite chemical relation *to each other*. Not always can such slags be produced by pre-adjustment of material, unless the ore used is of exceptional simplicity in composition. Conventionally, by the transformation (on paper) of one base into the "equivalent" proportion of another base, such formulas may be brought about, as will be shown later in the present article. Such adjustments are useful; their limitations, however, should be understood.

To illustrate the theory of a perfectly formulistic slag, suppose we require that our slag shall have the formula:

$$Fe_2SiO_4 + Ca_2SiO_4$$

in which expression Fe and Ca must be regarded as having their atomic ratios, i.e., 56 and 40. This formula is better written:

$$(FeO)_2SiO_2 + (CaO)_2SiO_2$$

so as to show at a glance the "singulo" form, i.e., oxygen in the base equal to oxygen in the silica. We shall retain hereafter the old "dualistic" form for these and other silicates.

This would be called a perfectly "formulistic" slag. Again, we may require that the slag shall contain two molecules of ferrous silicate to one of lime silicate, or:

$$2\,(FeO)_2SiO_2 + (CaO)_2SiO_2$$

In these and similar cases we may call the slag "strictly" formulistic.

In practice, however, another form will be far more common, the one, namely, in which, although we can obtain the proper relation of silica to each base, it is not practicable to obtain a definite relation in a chemical sense of the bases *to one another*.

We are here considering only the case of di-basic slags.

Such a slag we may call, to coin a term, "semi-formulistic."

For example, retaining iron and calcium for illustration, we may have a slag whose general form is:

$$x\,(FeO)_2SiO_2 + y\,(CaO)_2SiO_2$$

in which x and y are in their relation to each other indeterminate. Such a slag is still a "singulo" silicate in that the oxygen ratio of silica is maintained, but it is no longer in the perfect form indicated in the first example.

Percentage slags may also be classified, though for the purpose of this article this is not necessary. It is no infrequent matter to see a furnace run on the simple requirement that the slag shall show the silica always between certain limits, ex. gr., 35 to 40 per cent.

As we have already shown how to transform any formula into percentage, and have further indicated that we shall show how to calculate any slag in this manner, it might well be asked: "Why go into formulas at all?" There are several reasons; we content ourselves here with the general one, that it has been found unadvisable to omit methods by "excess" entirely. There is no escaping it in "taking out" a matte, and there are other cases where it is better to have a knowledge of chemical relations. This becomes indeed indispensable for the reading of most metallurgical works, in which such knowledge is assumed on the part of the reader. Having, then, outlined these principles, we shall show how to apply them in certain cases. It will soon be seen that as complexity in the problem increases, the method by "excess" becomes more and more difficult, and

per contra, the method by equation applies as well to the complex as to the simple problem.

Calculations for Matte.

Before analyses of material can be subjected to calculation for the furnace charge, they must first undergo two preliminary clearances. The first of these is the "taking out" of the matte. The second is the adjustment of bases, sometimes called "adjudication," by which is meant the allotment of certain of them, in their respective chemical ratios, so as to classify several bases under one head.

Both of these have as objects the simplification of the subsequent calculation for slag formation.

It is necessary that the calculation for matte should come first. It is only when all the bases which may be supposed to form matte or speiss are removed (i.e., by calculation) from the data that we can proceed to compute the reactions of silica with the bases remaining.

Briefly: Since in the actual operation of the furnace the sulphur and its accompanying metals drops out in the form of matte, leaving the slag as a separate product, so in the computation we take out, theoretically, what the furnace is expected to do actually.

Then (matte being out of the way) before computing the relations of the slagging materials it has long been seen that the attempt to formulate each base into line was a problem far more curious than practicable, when the bases exceeded two in number. Hence the practice, familiar to metallurgists, of conventionally transforming bases into their chemically equivalent quantities as compared with either iron oxide or lime.

A "matte" is chemically very difficult to define. We are here concerned but little with the theory of its formation. Essentially, it is a complex sulphide, which separates, owing to its greater specific gravity and also because of its radically different chemical nature, from either metal or slag, sinking below the latter in the operation of smelting. A "speiss" is a basic arsenide, often of iron alone, sometimes with other metals, formed under conditions entirely similar to those which give rise to matte.

A matte may be the only commercial product in smelting, in which case its composition almost invariably includes both copper and iron. This is not a treatise on working conditions, hence much is omitted that does not bear directly on the subject of computation. We merely note here that matte is often formed when the chief product is metal (especially in lead smelting), and that in somes cases its expected total weight is so small that computations are made without regard to it.

We are confronted with uncertainties in matte calculation. Given, let us say, an ore which has been partially roasted, but which still contains a considerable percentage of sulphur, the estimate as to how much of that element will be dissipated (in fumes or gas) and how much will be found as a true "product" in the matte is a matter rather of special experience than of calculation.

This experience has regard to composition of the charge, degree of oxidation, and conditions which determine the latter, ex. gr., shape of the furnace, blast, fuel ratio and other considerations. In the extreme case of "pyritic" smelting, especially when the ratio of coke is small, nothing but practice based on careful observation will serve to maintain the desired balance. A function of the blast (aside from its burning the fuel proper), is to burn both sulphur and iron, the burnt sulphur leaving the stack as SO_2, the burnt iron entering the slag as silicate. The residual (unburned) sulphur combines or retains its combination with unburned metals to form the compound known as "matte."

Various assumptions may be made as to the conduct of sulphur in the operation of smelting, and as to the distribution of the metals as well. Thus, zinc in the same run, may be found in fumes, matte and slag; so may lead. Iron is almost invariably divided between matte and slag (in operations where any matte is formed), while copper which in the matting furnace should be thrown entirely into matte, may by excess of oxidizing influences be carried into the slag to an extent destructive of profits.

Hence it is that writers on the detail of matte estimation are disposed to base the calculation upon certain assumptions regarding the probable destination of fractional parts of both sulphur and of metals. These assumptions are themselves based upon actual experience. Having made them, ex. gr., having assumed that one half of the sulphur will enter the matte and that one fourth of the zinc will be carried into fumes, the supposed residual quantities will form the basis of our calculations. Estimates of this kind are liable to considerable uncertainty if the furnace varies much in action, as, to cite a not uncommon case, when oxidation falls below its expected total, resulting in too high a percentage of iron in the matte, with corresponding low percentage of copper. The reverse of this condition might lead to oxidation of copper and its consequent unprofitable presence in the slag.

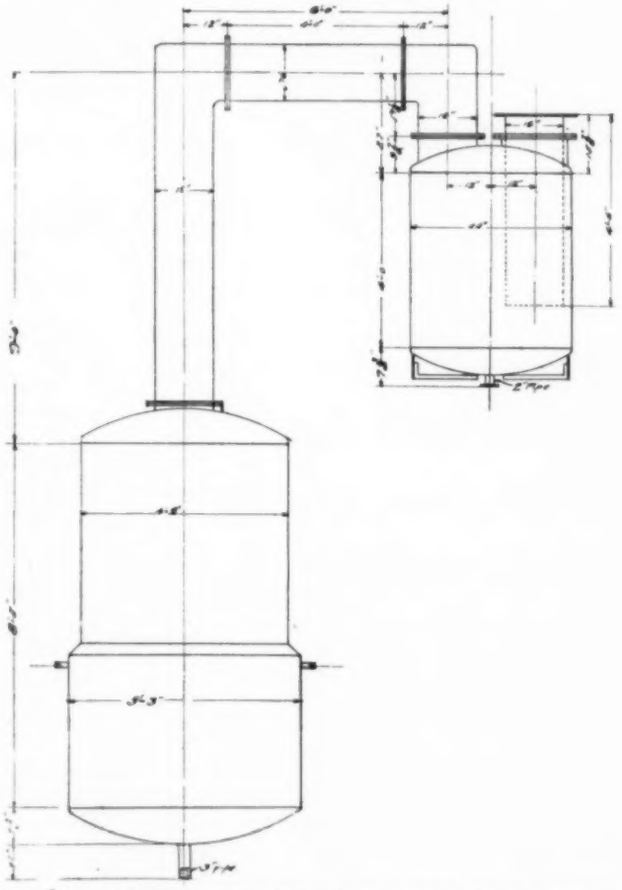


FIG. 63.—ENAMELED JACKET VACUUM PAN WITH JUICE CATCHER.

These remarks are sufficient to indicate the distinction we make between "guesses" as to these distributions, and the calculations based on them. Generally, the computation of matte formation lacks the accuracy of a slag calculation, which is based upon a mixture free or nearly free from the "side issue" of matte fall.

Calculations for matte should always be based on stoichiometric data, i. e., on chemical ratios according to atomic or molecular weights. These, however, are of the simplest description, and may be briefly epitomized in the general statement that copper is computed as its subsulphide, Cu_2S, iron as FeS, while zinc and lead, when it becomes necessary to provide for them at all, may be put in as ZnS and PbS respectively. We shall not consider the mattes resulting from further "concentration," which may be considerably lower in sulphur.

As we have assumed the atomic weight of copper as 64 for these computations, we "adjudicate" copper subsulphide as 128 copper to 32 sulphur, that is, as 4:1.

Iron, as FeS, takes the ratio of 56 to 32, always simplified into 7:4.

Zinc sulphide whose exact ratio is Zn 65, to S 32 may be safely computed in the ratio of 2:1.

Finally, lead sulphide, whose exact ratio is Pb = 207 to S = 32, is not reducible to any very simple ratio; 65 to 10 is quite close enough, but does not gain much over the original weights in simplicity.

In the common case of very small weight of lead figured into matte, six to one would suffice.

We now give our first example, making it simple both as to composition and as to the assumptions.

Examples. (a) Partially roasted ore contains:

Copper	7.6 per cent
Iron	16.8 per cent
Sulphur	7.0 per cent

Assume that all of the copper and all of the sulphur will enter the matte and that all iron will enter the slag except as taken by the sulphur left after the copper is satisfied. If we taken 100 lb. of ore, what will be weight of the matte and what will be its analysis?

Solution. We start (as always) with the copper, as the metal with the greater affinity for sulphur. We have:

$$Cu_2 : S = 4 : 1 = 7.6 : 1.9$$

that is, the copper will take up 1.9 lb. of sulphur. Subtract this 1.9 from total sulphur of the analysis: 7 — 1.9 = 5.1; this 5.1 is the sulphur which is to be apportioned to iron. The latter being obviously in excess, it is convenient to place sulphur first in our next proportion.

$$S : Fe = 4 : 7 = 5.1 : 8.9$$

neglecting second decimals of a pound. That is, 8.9 lb. of iron will go into matte. We have now for the weight and composition of the matte:

	lb.	Percentages.
Copper	7.6	32.34
Iron	8.9	37.87
Sulphur	7.0	29.78
Weight	23.5	99.99

No "predicted" analysis can in practice be stated thus accurately. In this case the rough approximation: Cu = 30, Fe = 40, and S = 30 would be as close as could be reasonably expected.

(b) We have in an ore:

Copper	3.00 per cent
Iron	10.00 per cent
Sulphur	4.00 per cent
Arsenic	1.00 per cent

Take out matte and speiss, under the assumption of no losses, figuring speiss as Fe_3As. (Simple ratio for As to Fe is 15 : 56.)

First figure out the copper, then the arsenic, then remaining sulphur to remaining iron.

$$Cu_2 : S = 4 : 1 = 3 : 0.75$$
$$As : Fe_3 = 15 : 56 = 1 : 3.7$$
$$S : Fe = 4 : 7 = 3.25 : 5.7$$

From the 4 per cent sulphur we take the 0.75 required by copper; remains 3.25 which figures in the last proportion. Iron taken is: by arsenic, 3.7; by sulphur, 5.7; total, 9.4 lb. Total lbs. and analysis of matte:

Matte and Speiss	lbs.	Analysis.
Copper	3.0	17.24 per cent
Iron	9.4	54.02 per cent
Sulphur	4.0	22.99 per cent
Arsenic	1.0	5.75 per cent
	17.4	100.00 per cent

We here quote from Prof. Peters' work on "Modern Copper Smelting."

"Taking the contents of copper in the charge as a standard for comparison, sufficient sulphur should be alloted to it to form Cu_2S, excess of sulphur remaining being supplied with sufficient iron to form FeS. If other metals are present such as lead, zinc or manganese, three fourths of the former, one half of the second or one fourth of the latter may be first considered as forming monosulphides. If the rate of smelting be slow, and considerable lime or magnesia be present, 5 per cent of the sulphur should be deducted before beginning the calculation, and if the furnace be a reverberatory the resulting matte will average 8 per cent higher in copper than is found by this formula."

This must be considered as applying to copper smelting only, not at all as to lead or other metals.

We give an example based on the above assumptions of Prof. Peters. However, there is not the slightest difference in method under any "assumption" since the latter requires only certain subtractions to be made before starting the adjudications.

(c) We have an ore which analyses as to matte ingredients:

Copper	5.0 per cent
Iron	9.0 per cent
Zinc	6.0 per cent
Lead	2.0 per cent
Sulphur	8.0 per cent

"Take out" the matte under the above suggestions of Prof. Peters, also allowing that 5 per cent of the sulphur is excluded from the matte. This leaves 7.6 per cent sulphur for the computation, 1.5 per cent lead and 3 per cent zinc.

We have:

$$Cu_2 : S = 4 : 1 = 5 : 1.25$$
$$Zn : S = 2 : 1 = 3 : 1.50$$
$$Pb : S = 65 : 10 = 1.5 : 0.23$$

2.98 required sulphur.

Let us say 3 per cent sulphur for the three metals considered, then taking this from the 7.6 "available" sulphur we have left 4.6 per cent to be adjusted to iron. Iron is in excess over sulphur remaining; put sulphur first in your proportion.

$$S : Fe = 4 : 7 = 4.6 : 8 = \text{lbs. iron.}$$

We may now write composition of the matte in pounds, also analysis. The latter we state to nearest whole figures only.

	Matte, lbs.	Analysis.
Copper	5.0 lbs.	20 per cent
Iron	8.0 lbs	32 per cent
Zinc	3.0 lbs.	12 per cent
Lead	1.5 lbs.	6 per cent
Sulphur	7.6 lbs.	30 per cent
	25.1 lbs.	100 per cent

Adjustment of Bases.

Having shown how to set aside the elements for matte-fall with greater or less accuracy, we come to the final preparation by substitution of bases. It is true that there are other allowances to be made, for possible losses by volatilization, but these can hardly be formulated. They may be reduced, by careful observation of furnace products, to some definite figures, after which, if necessary, due allowance may be made for them in the charge.

If, for example, in smelting an ore high in zinc, analysis of the products shows a loss of one-fifth of same, unaccounted for, such a loss would become part of the computation data. However, such allowances are merely omissions of the presumed losses from the weights or percentages shown by the analyses.

It has already been said that it may be a matter of complexity to make separate figures for each and every base. Accordingly, we "lump" two or three bases into one calculation. This may be done in either one of two ways, viz.:

(1) Weight for weight.
(2) Stoichiometrically.

A third method has been recently called to the writer's attention. It has the merit of extreme simplicity, and consists in treating a certain base as if it did not exist, i. e., calculating the charge without the least reference to it, and "trusting to luck" that it would be "carried." The only base so far known to have been treated in this manner is alumina, and that only to a maximum of a possible 10 per cent in the slag.

There is, however, a quite common practice of calculating a slag on the basis of 90 per cent total, instead of 100, putting silica in the calculation a little higher than necessary (theoretically), and explaining the procedure much as above, viz.: the 10 per cent deficit in the calculation represents unreported (or neglected) bases, and, like the operator who disregards his alumina, the smelter "trusts to luck" and silica to see him through.

Returning to (1). Suppose we are to compute a charge, and that we have an ore with:

Fe_2O_3	10 per cent
MnO	3 per cent

Also, we have a limestone with:

CaO	50 per cent
MgO	2 per cent

We know that FeO = 72 and MnO = 71 in molecular weights. It is useless to apply such minute differences in practice. In this case we should "prepare" the ore for its slag computation by taking 0.9 of the Fe_2O_3 as $(FeO)_2$, and adding the MnO, thus:

Iron oxide, 10 × .9 =	9 per cent
MnO =	3 per cent
FeO =	12 per cent

As to the limestone, it is hardly worth while to consider 2 per cent of MgO stoichiometrically. Note that it is only because of the small percentages that this case is so summarily dismissed. We would here say "CaO 52 per cent" and proceed so to calculate; that is simply adding the MgO to the CaO.

This "weight for weight" will sometimes serve, and often does, but it is better to come at once to plan (2) and make stoichiometric substitutions, i. e., by relative atomic weights. There is much that is conventional about even this method of treatment, albeit it may become necessary.

The assumption underlying this substitution of one element for another must be that the displacing element will act in a manner similar to the one displaced. As there is no actual displacement, we might better say that we assume that each element will, when used in its atomic ratio, act in the same manner as the one to whose basis we figure it. This is by no means always true, the simplification by this artifice being a convention for the reduction of slags to certain "type" forms.

Take the case of zinc oxide. If we have to treat it as the component of a slag it must go into the lime group, and its percentage will be multiplied by 0.7. (Example, if we had 7 per cent zinc we should compute it at 7 × .7, say 5 per cent.) The result will be that, in computing for addition of limestone to the flux, we shall use less lime, because we have already a certain amount of "conventional" lime in the shape of calculated lime, which is really zinc.

Here is a case "by contraries" instead of by similarities. The more lime in the slag the worse the carrying power for zinc; in fact there comes a point where the slag refuses to carry any more zinc, and when the slag is very high in lime it cannot carry zinc at all.

Thus, putting zinc into the lime column is far from indicating that the two act alike, but a purpose is subserved nevertheless, for the *actual lime* is diminished, as it should be if the addition of zinc is inevitable.

The process of substitution of one base for another consists simply in computing a given weight of a certain base into its equivalent weight in another base, these "equivalent" weights being in the ratios of the molecular weights of the bases.

Illustration. We have a limestone whose analysis shows CaO, 39 per cent, MgO, 9 per cent. Stoichiometrically, we have:

MgO : CaO = 40 : 56 = 1 : 1.4

That is, one part of MgO can carry as much silica as 1.4 parts CaO. Accordingly we may multiply MgO by 1.4 and then add in the product as CaO.

Thus, 9 × 1.4 = 12.6 and in our computation for limestone in slag we get:

CaO by analysis	39.0 per cent
CaO by conversion	12.6 per cent
Conventional lime, for computation	51.6 per cent

The excess figured from the analysis *is not affected by this substitution*, a point we leave the student to verify for himself.

Conversion Factors.

Iron and Manganese. The metals have as atomic weights 56 and 55, their protoxides are FeO = 72 and MnO = 71. Hence it is not worth while to use any factor. Reduce all iron to basis of FeO, and all manganese to basis of MnO if not already so reported, then add the FeO to the MnO as in above example.

Alumina. This acts sometimes as acid and sometimes as base. We here dismiss the case of the acid action of alumina. Opinions differ as to how to group it. We have already noted that some "dodge" the question by not including it at all in apportionment of base to silica.

Take any of the ordinary relations, say bi-silicate, we have:

Al_2O_3, $3SiO_2$ and $(CaO)_3$, $3SiO_2$.

In relation then, to saturating power we have Al_2O_3 : 3CaO = 102 : 168 and since 102 : 168 = 1 : 1.65, we may assume 1.65 as factor for "conversion" of Al_2O_3 into CaO.

Magnesia. This has already been shown to have factor 1.4. Example, 10 per cent MgO = 14 per cent CaO.

Baryta. BaO : CaO = 153 : 56. In this case we have a factor much less than unity. Strictly, 153 : 56 = 1 : 0.366, but in practice 0.4 has been adopted.

Zinc. ZnO : CaO = 81 : 56. The factor adopted for "converting" ZnO into CaO is 0.7.

Those last two, (Ba, Zn) are not desired in any slag. Zinc is the more objectionable. The action of barium is somewhat uncertain, as under strong reducing action in the presence of sulphur its sulphate drops to sulphide, and joins the matte, chemically at least, though not always separating well.

Examples of simplification. (a) We have an ore whose analysis give (slag constituents only):

Silica	28 per cent
Ferrous oxide	36 per cent
Alumina	8 per cent

Also a limestone, analyzing:

Silica	6 per cent
CaO	46 per cent
MgO	4 per cent
Al_2O_3	4 per cent

Simplify these by substitution, according to rules above: *Answers.*

Ore.		Limestone.
SiO_2 28	per cent.....	6 per cent
FeO 36	per cent.....	.....
CaO..... 13.20	per cent.....	58.2 per cent

(In ore 8 × 1.65 = 13.20. In limestone 4 × 1.4 = 5.6 and 4 × 1.65 = 6.6. 46 + 5.6 + 6.6 = 58.2 per cent lime.)

One more example will illustrate a complete operation, viz.: both the "taking out" of the matte and the subsequent adjudication of bases.

(b) Take the following copper ore analysis; *assume* that one-third of the zinc goes off in fumes, one-third into the slag.

one-third into the matte; all copper goes into the matte; one-fourth of the sulphur is dissipated; also, in matte formation the copper and the one-third of the zinc take precedence of the iron, so that it is only the "residual" sulphur that can be apportioned to the latter metal. We figure on 100 lb. of ore.

Then, the matte being out, simplify the bases and present revised analysis as basis for slag computation.

Original Ore Analysis.

Silica	36	per cent
Alumina	8	" "
Baryta	4	" "
Magnesia	6	" "
Lime	6	" "
Manganous oxide (MnO)	4	" "
Iron (metallic)	12	" "
Zinc	6	" "
Copper	6	" "
Sulphur	9	" "
Deficit (Oxygen, etc.)	3	" "
	100	" "

Solution. One-fourth of 9 per cent sulphur = 2.25. Sulphur available for matte = 6.75.

$Cu_2 : S = 4 : 1 = 6 : 1.5 = S$ in Cu_2S.

$Zn : S = 2 : 1 = 2 : 1 = S$ in ZnS.

Sulphur with Cu and Zn = 2.5

$6.75 - 2.5 = 4.25 = S$ for FeS.

Also, $S : Fe = 4 : 7 = 4.25 : 7.46 = Fe$ in FeS.

Now figure pounds and analysis:

	Pounds.	Analysis.	
Copper	6	27.0	per cent
Zinc	2	9.0	" "
Iron	7.46	33.6	" "
Sulphur	6.75	30.4	" "
	22.21	100.0	" "

We now simplify the bases, by factors shown above. Ore, with matte out and bases "converted" reads as follows:

Silica	36.00 lb.
CaO	30.95 lb.
FeO	9.84 lb.

The CaO is made up as follows:

Al_2O_3	8	× 1.65	=	13.20
BaO	4	× .4	=	1.60
MgO	6	× 1.4	=	8.40
CaO	6	× 1	=	6.00
ZnO	2.5	× .7	=	1.75
				30.95

The Electrolytic Determination of Lead in Large and Small Amounts, Using a Gauze Cylinder Anode.

By Bruno Woiciechowski.

Among the articles published by various workers on electrolytic methods for the determination of lead, there seems to exist a lack of description of exact conditions necessary for the rapid deposition of PbO_2 on a gauze cylinder anode with a rotating cathode.

Prof. E. F. Smith in his book on Electro-Analysis recommends the use of a sand-blasted platinum dish to secure an adherent deposit, but in a technical laboratory the use of a dish is not practicable.

J. G. Fairchild describes in the *Journal* of Ind. and Eng. Chemistry conditions that must be observed to get a good deposit on a smooth cylinder with stationary electrodes. This is of merit, although the amount of PbO_2 that can be obtained in an adherent condition is limited to 0.3 gram.

The conditions that are good in these cases are not satisfactory when different forms of electrodes are used.

At present, most of the metallurgical laboratories that are using electrolytic methods are furnished with gauze cylinders and rotating propeller-shaped anodes. The description of conditions that have been found necessary in this laboratory to obtain a good deposit of PbO_2 on a gauze cylinder will, no doubt, be of some value to those who are using this device.

The method, as it is used for lead base babbitts, is as follows: The tin and antimony are separated from the lead and copper by means of sodium sulphide. The sulphides of lead, and copper when it is present, thus obtained, are dissolved in a known amount of HNO_3 (10 cc), filtered, the sulphur and filter paper burnt, the residue dissolved in a little HNO_3 and added to the main solution, which should be in a tall electrolytic beaker of 200 cc capacity. Sufficient HNO_3 is added to make a total of 45 cc of strong HNO_3 in 150 cc of solution.

The electrolyte is heated till it starts to boil and electrolyzed with 3 amp for a minute or two, or till the deposit is brown in color, then with 5 amp for 20 to 30 minutes.

The deposit must be dried at the usual temperature for PbO_2, viz.: 230 deg. C. for 20 to 30 minutes, depending on the amount of deposit.

The conversion factor is used as given by Prof. Smith, 0.8643, instead of the theoretical 0.8660.

The deposit will be so adherent that it will not come off when rubbed with the finger; a finger nail may scratch it off, however, so the electrode must be handled with care while disconnecting, drying, and dessicating. It is a good idea to have in the drying oven an adjustment for hanging the electrode. A binding post fastened to the wall of the oven will answer the purpose very well.

When other metals, especially copper, are present in large amounts, and Pb does not exceed 10-12 per cent, the amount of HNO_3 may be considerably reduced, and this is usually the case with brasses. In this case to the filtrate from metastannic acid sufficient HNO_3 is added to have 10 cc in a total volume of 150 cc. The solution is heated to boiling and electrolyzed with 5 to 6 amp for 15 minutes. The deposit will range in color from golden brown to dark brown and may be dried completely at the usual temperature of the drying oven, viz., about 105 deg. C.

If copper is to be determined after lead it will be found better to have more HNO_3, say about 20 cc, in 150 cc of solution. Then less Cu will be deposited on the cathode, which must be dissolved off before neutralizing and subsequent acidifying the solution for Cu deposition.

At present this laboratory uses a magnetic rotating apparatus called the Frary solenoid, a description of which may be found in "Electro-Analysis," by Smith, and in "Technical Analysis of Brass," by Price and Meade. It has proven to be the best apparatus adopted for the deposition of PbO_2 especially when lead is present in very large amounts. The conditions are identical with those described for a rotating anode device. With this apparatus a number of depositions of PbO_2 are made daily, the amount of PbO_2 deposited ranging from 0.0005 gm to 2.00 gm, without any difficulty.

In conclusion, therefore, the author feels justified in highly recommending the solenoid, as it gives the most satisfactory deposits, not only of PbO_2 but of all the metals which can be electrolytically determined.

Lumen Bearing Company, Buffalo, N. Y.

Of the "Chemist-Analyst," the excellent little journal published periodically by the J. T. Baker Chemical Company, of Phillipsburg, N. J., No. 3 has just appeared and contains besides useful information on various analyses, an illustrated article on the manufacture of chemically pure nitric acid, an article by George J. Hough on the determination of iron, and a description by George R. Michener of a convenient wash-bottle mouthpiece.

The Production of Oxygen in the Workshop.

The Production of Oxygen from Bleaching Powder.

BY AUG. S. NEUMARK.

The precise nature of bleaching powder (chloride of lime) has not been satisfactorily demonstrated; but it is generally regarded as a chemical combination of calcium hypochlorite and calcium chloride, which may be expressed by the chemical formula: $CaOCl_2$. It also contains small quantities of basic calcium hypochlorite CaOCl.OH and basic chloride CaCl.OH, and there is always present an excess of lime and a certain quantity of water. It is manufactured by electrolytical processes in various strengths containing anywhere between 20 and 40 per cent of available chlorine.

That bleaching powder could be used for the production of oxygen has been known since 1829, when Dingler first obtained this gas by heating chloride of lime with certain metallic oxides (cobalt, nickel and copper). Later the wet process of decomposing bleaching powder was resorted to and various methods were subsequently proposed by Mitcherlich, Stalba, Winkler, Fleitmann, and lately by Jaubert.

If a clear and concentrated solution of the powder, to which has been added a small quantiy (0.1 = 1 per cent) of the oxides of cobalt, nickel, copper or iron (or the salts of such oxides), is gently heated to 70 to 80 deg. C., 158 to 176 deg. Fahr., oxygen gas is given off in a slow and regular stream. It is not necessary to heat any further, since when once started the reaction continues until all the oxygen from the hypochlorite has been disengaged.

Instead of a solution, a paste made of bleaching powder and water may be used. In that case, however, it is necessary to add some paraffin oil, or a piece of paraffin. The oil or the molten paraffin, floating on top of the pasty liquid, prevents frothing of the mixture, which otherwise would occur. The oxygen escapes with effervescence in quantities equivalent to the active chlorine.

Although a number of salts and oxides (ferric hydrate or manganese dioxide may also be used) may serve as a contact substance, it seems that cobaltic oxide (cobalt peroxide) is the one which is most prompt and energetic in its action, and that relatively small quantities of it are required for the reaction.

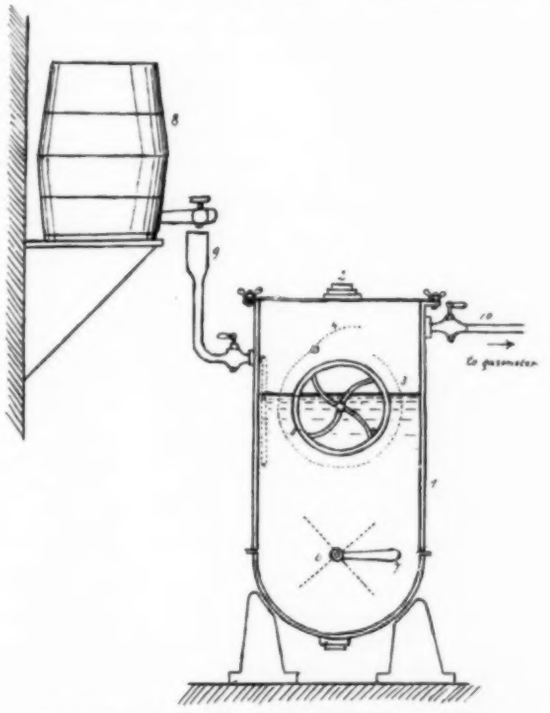
The oxygen obtained is quite pure; the free lime which is always present in the bleaching powder sufficiently prevents the disengagement of chlorine.

A modification of this process is the one proposed by Fleitmann. A suitable vessel is filled with milk of lime to which has been added some cobaltic oxide. A constant stream of chlorine is then allowed to pass through the fluid, causing the disengagement of a like amount of oxygen. The latter will be found to be almost free from chlorine, even if the gas should be introduced in a rapid stream. Only when the calcium hypochlorite is entirely decomposed will the oxygen be mixed with chlorine, which can easily be removed by passing it through a solution of caustic soda. This method can be used to advantage only where manganese dioxide and muriatic acid (the essential chemicals for generating chlorine) can be obtained cheaply enough.

The production of oxygen from bleaching powder has at various times been the subject of attempts to adapt it to industrial requirements or to the requirements of the individual consumer of oxygen. A simple generator for that purpose had been proposed fifty years ago by Varrentrapp. An ordinary acid-carboy is partly filled with the chloride of lime mixture and is then closed up by a tight-fitting plug, having an exit pipe of sufficient width. This carboy—basket and all—is placed into a wash kettle or the like, and the water is heated to boiling. The contents of the carboy will yield 1000 to 1200 liters (35 to 43 cu. ft.) of oxygen. Fleitmann recommended the use of steam-jacketed boilers, where the gas can be obtained under a higher pressure and also in large quantities.

Jaubert recommends the following: 100 parts of the dry bleaching powder are mixed with 1000 parts of cold water and allowed to settle. The clear liquid is decanted into the generator. To this is added, while stirring, a concentrated solution of 8 parts of crystallized cobaltic chloride. The reaction is said to last five minutes, while it would take from 1 to 2 hours if but 2 parts of cobalt salt was used. The only objection that could be raised against this method would be the rather high cost of the catalytic substance.

It may also be mentioned that in most of these methods some of the calcium hypochlorite is liable to be transformed into the chlorate, which, of course, lessens the output of oxygen.



OXYGEN GENERATOR, USING BLEACHING POWDER.

Three pounds of bleaching powder titrating 35 per cent of active chlorine should yield about 2½ cu. ft. of gas.

In 1903 Geo. F. Jaubert succeeded in finding new and extremely active catalytic substances which were much cheaper than cobalt salts and which cause a rapid generation of oxygen even in the cold. Such substances are the sulphates of iron and copper when used in combination; if used alone the decomposition is an extremely slow one, even if heat is employed.

The proportions as proposed by Jaubert are 60 parts of dry bleaching powder mixed in a suitable vessel with 350 parts of water. This mixture is poured into the generator. To start the reaction a solution of 12 parts of sulphate of iron (or manganese) and 3 parts of sulphate of copper in 50 parts of water is slowly added, while stirring. It is probably better to mix the copper sulphate solution with the bleaching powder and add the iron salt solution when required.

Several welding shops in this country have adopted this or at least similar methods for producing oxygen. As a modification of this process the dry bleaching powder (220 lb.) may be mixed with dry sulphate of iron (33 lb.) and sulphate of copper (11 lb.). This powder evolves oxygen when placed in water. Epurite is a trade name for such a combination. The gas can be generated in an apparatus similar to calcium carbide generators. The generators should be provided with suitable stirring devices (paddles) and suitable apertures for introducing the chemicals and removing the residue. The exit tubing is connected with a scrubber to remove any impurities, and from these leads to the gas holder.

The accompanying sketch shows a generator of this kind, the invention of B. Artique (Brit. Pat. 14,848, of 1904). The apparatus is made of sheet iron, having a tight-closing cover 2. A perforated cylinder is placed inside the generator, the chloride of lime being introduced through a door 4. This cylinder can be rotated by means of a wheel 5. The agitator 6, having a handle 7, serves to stir up the deposit of calcium chloride. The solution of sulphates is contained in the reservoir 8, from where it passes into the generator by means of a funnel 9 and a pipe reaching below the water level. The gas evolved passes through the pipe 13 to the gas holder. Two such generators may be used alternately.

Where a larger supply of oxygen is required it would be preferable to use cast-iron generators, topped by a dome or a "gooseneck," to which is attached the exit pipe; or a lead-lined double-jacketed copper kettle may be used. Heating, although not necessary, hastens generation; the temperature should, however, not exceed 80 deg. C. The feed pipe for the solution of sulphates should reach more than half way down the "milk" of bleaching powder; it will then, at the same time, act as a safety pipe.

It may also be mentioned that the catalytic agent may be suspended in cylinders made of porous material which are immersed in the liquid. This modification had first been proposed by Jaubert, but a patent on a generator of this type has only recently been granted to M. Mauran and J. H. MacMahon (U. S. Pat. 1,001,873, Aug., 1911). In the latter case the metallic oxides are mixed with Portland cement or baked clay and are used in connection with "lavoisite."

The oxygen may also be produced under pressure, as the latter does not prevent decomposition of the bleaching powder. E. H. Kirkpatrick, who has experimented along these lines, found that evolution of oxygen takes place at a pressure of 10 and even 15 atmospheres (150 to 225 lb.).

If the dry bleaching powder is mixed with small quantities of slaked lime, and heated to redness, oxygen is also given off (H. Deville).

Bleaching powder has no dangerous properties, therefore large quantities may be stored. All the work connected with the generation of oxygen can be done by unskilled labor. The chloride of lime usually titrates 33 to 35 per cent of "available" chlorine. It is sold in barrels, drums or casks at about 1½c. per lb. The cost of oxygen does not exceed 2c. per cubic foot; this process, therefore, compares favorably with the chlorate process.[1]

It may be added that instead of bleaching powder any other alkali-hypochlorite may be used, or the solutions of these hypochlorites (Javelle water, Labarraque water).

Metallurgy of Molybdenum.

A recent publication of the Mines Branch, Department of Mines, Canada (Dr. Eugene Haanel, director), contains a report on the Molybdenum Ores of Canada, by Dr. T. L. Walker. While the greatest part of the bulletin is devoted to a review of the Canadian molybdenum deposits, there is also an interesting introductory chapter on some phases of the metallurgy of molybdenum from which the following information is taken.

The chief molybdenum ores are molybdenite MoS_2, molybdite MoO_3 and wulfenite $PbMoO_4$.

Concentration of Molybdenite.

According to Dr. Walker, the preparation of the crude ore for the market is one of the most difficult problems in ore dressing. Up to the present it is doubtful if a satisfactory solution has been arrived at. The mineral is very soft, and usually occurs in a very hard gangue, largely quartz and feldspar. In attempting to crush by stamps or rolls, much of the molybdenite is finely divided, so that a large loss results by sliming. On the other hand some of the larger flakes resist the action of the rolls, and may be separated by means of sieves. In density, molybdenite is heavy enough to separate readily by washing, were it not for its perfect cleavage giving rise to very thin scales and plates, which readily float away and are lost.

In general there are three methods of molybdenite concentration which may be applied after cobbing and hand picking:

1. The ore may be crushed and concentrated by washing. Mr. J. Walter Wells some years ago carried on experiments with this method of treatment in view. A brief report of the results of this work is given in the following extract from *Mineral Industry*, 1903, page 478.

"Experiments were carried out by Mr. Wells for the purpose of finding suitable methods for concentrating the Canadian ores. On a sample containing 50 per cent pyrrhotite, 10 per cent pyrite and 6.5 per cent molybdenite in a gangue of calcite, biotite, quartz and pyroxene, good results were obtained by crushing in a jaw crusher, hand picking of the large flakes of molybdenite, recrushing in rolls set to 0.2-in. space, and successive sizings in screens from 0.3-in. to 0.5-in. mesh. The oversize from the screens, which consisted of molybdenite, mica and rock, was treated on a Wilfley table and yielded a commercial product. The Hartz jig was not adapted for concentrating this ore, but good results were obtained with the Wetherill magnetic separator, although, owing to the high current and slow speed necessary, it is doubtful if this separation can be done on a practical basis. Treatment by a modified form of the Elmore process was only partially successful, as the large particles of molybdenite were not affected by the oil. Another sample consisting of quartz and feldspar with 2.5 per cent molybdenite, was crushed and sized, but gave no clean ore on any of the screens. The whole sample was then ground to pass an 0.05 screen, and concentrated on a Wilfley table; the final concentration being effected by the oil process. The experiments carried out by Mr. Wells showed that no standard method can be adopted for concentrating molybdenum ores. Separate tests are required to determine the proper treatment.

2. Crushing and dry concentration has been employed at Copper, Maine, where the ore is granite, containing fairly coarse foliated molybdenite. The history of the concentrating operation of the American Molybdenum Company is briefly told by Mr. Hess (Bull. 340, U. S. Geol. Surv.) as follows:

"The plant consisted of a 35-hp boiler and engine, a Sturtevant jaw crusher and roll, and four sets of special rolls, each 3 ft. in diameter and 10 in. wide. The crusher was only a couple of feet above the floor, from which the material, crushed to about ¼-in. square, was elevated to the Sturtevant roll, 18 in. in diameter by 4 in. wide, which reduced the ore to about ⅛ in. It was then elevated to a bin at the top of the building, from which it fell to a series of two special rolls, thence it was elevated to a third special roll, and run through a 34-mesh screen. The molybdenite caught on the screen was delivered to a box at the end. The material going through the screen was carried by an elevator and screw conveyor to a fourth roll, from which it fell onto a 40-in. screen and from that to a 60-mesh screen. What went through the 60-mesh screen was elevated and sent to the tailings pile. It is readily seen that the repeated elevations of the material meant a considerable waste of power. The mill ran only six weeks, and it is said to have made about a ton of concentrates, a portion of which seen by the writer was very clean. In the tailings some fine flakes of molybdenite were found, but the amount seemed small. Such a process, if mechanically perfected, might work profitably on deposits where, as in this one, the molybdenite flakes are comparatively broad, but would be wholly unsuited to deposits like many of those in Colorado and elsewhere, in which the individual flakes are of almost microscopic size."

3. A process apparently well suited to molybdenite ores has been recently brought forward by F. E. Elmore. The Elmore flotation process was described in an illustrated article in our

[1] See the article in this journal, Vol. IX, page 641 (December, 1911).

Vol. VI, page 187 (1908). Its essential features are the use of oil to float the metallic particles and the employment of a partial vacuum.

At the testing plant of the manufacturers of the Elmore flotation apparatus in London three tests on concentrating molybdenite resulted as follows:

Sample Number.	Nature of Gangue.	P. C. Molybdenum In Ore.	In Tailings.	In Concentrates.	P. C. Saved.
1	Feldspar	3.40	0.25	40.80	93.2
2	Much garnet and magnetite	2.30	0.06	51.57	98.1
3	Not stated.....	5.21	0.17	54.7	97.0

A sample of the ore from the claims of the St. Maurice Syndicate, Lake Kewagama, was treated by this process by the Denver Engineering Works Company, of Denver, Col. The sample was small, but the concentration was very satisfactory, with a minimum loss in the tailings as illustrated by the following report:

"Following are the results obtained by the Elmore process on the sample of molybdenite submitted my Mr. J. C. Gwillim. The mineral seemed free at 16 mesh, but owing to the small diameter of the delivery tube of the laboratory machine it was found necessary to crush it finer before making the test.

"Five hundred grains of ore assaying 1.70 per cent molybdenum were agitated four minutes with 5 c.c. acid, 2 c.c. Beaumont oil, then four minutes with 5 c.c. acid and 1 c.c. oil; 2.5 c.c. acid were used for gas, and test was under vacuum 2.25 minutes. The following products were obtained:

20 grains concentrates.....42.90 per cent molybdenum
472 grains tailings.....trace

"This gives the ratio of concentration of 25 tons into one and a recovery of 100 per cent. The recovery of figures are slightly in excess of 100 per cent, owing probably to discrepancy of a few hundredths in crude assay. The tails showed acid reaction and were quite clean.

"The amounts of acid and oil used could probably be lowered very materially, but owing to the lack of time and urgent requests to rush the work these investigations were not undertaken."

At the Great Knaben mine, in southwestern Norway, which has produced from 25 to 30 tons of molybdenite annually since 1902, water concentration with jigs and tables has been abandoned, and more satisfactory results are said to have been obtained by the use of the Elmore oil concentration. The ore is first cobbed, and the poorer ore sent to be concentrated.

In 1899 Professor J. B. Porter, of McGill University, made some experiments on the concentration of molybdenite for the Geological Survey. From the two samples examined he concluded that the most satisfactory method was cobbing and hand-picking.

The following extract from the Report of the Geological Survey of Canada gives the main results of Professor Porter's investigations. (Report of the Geological Survey of Canada, Vol. 13, page 10, 1900.)

"The first, or Egan Township sample, weighing 289 pounds, and containing in all 15.92 per cent of molybdenite, was cobbed and hand-picked in the Survey, yielding 39 lbs. of clean mineral in crystalline flakes. The remaining 250 lbs. of the cobbed ore was then sent to Professor Porter, who ascertained that it still contained 2.8 per cent of molybdenite. By a dry process of rolling and screening, followed by jigging, nearly all the molybdenite was extracted from this ore, in a series of concentrates ranging from 70 per cent to 15 per cent molybdenite. It is not necessary to refer to the details of treatment here, but the results appear to show that in the case of molybdenite ore of this class, in which the crystalline masses are of considerable size, it would not be economically possible to employ any crushing and concentrating process. The problem resolves itself into one of cobbing and hand-picking at remunerative rates. The associated minerals in this case were: pyroxene, iron pyrites and mica.

"The second, or Ross Township sample, weighed 250 lbs. The gangue was chiefly quartz, and, although the molybdenite made a considerable showing, it was found by Professor Porter to amount to only about 1 per cent. This specimen was not cobbed or hand-picked. By concentration it was determined that about 52 per cent of the molybdenite could be saved in the form of a concentrate containing 33.50 per cent of the mineral. The grade of this concentrate appears, however, to be too low for present commercial requirements."

It is worthy of note that none of these processes has up to the present been employed very satisfactorily for the separation of molybdenite. It would seem as if a reasonable combination of the dry screening process for the removal of the coarser flakes, followed by a treatment of the tailings by the vacuum process, should give results superior to those obtainable from the employment of any one of these methods alone.

In New South Wales and Queensland, which produce a large part of the world's molybdenum ores, the molybdenite-bearing quartz is hand-picked, crushed through rolls, and then jigged. The oversize is recrushed, hand-picked again, and finally treated on Wilfley tables. (Mineral Industry, 1907, page 722.)

For the market the ore should be concentrated to about 90 per cent molybdenite, for which, at present, the current rate is about $550 per ton. The market rate, however, is very variable. The presence of even small quantities of copper, arsenic or bismuth, may render the ore less suitable, particularly for steel manufacture.

Uses of Molybdenum.

Until recently molybdenum was required only for the manufacture of chemical preparations, principally ammonium molybdate, which is much used in the determination of phosphoric acid. The iron and steel works of the United States alone are said to consume as a chemical reagent several tons of molybdenum annually.

Molybdic acid is used as a blue pigment in the manufacture of porcelain, and for dyeing silks and woolens. In various compounds molybdenum is used for coloring leather and rubber.

Ammonium molybdate is used for fireproofing, also as a disinfectant for cloth used in railway passenger carriages.

The chief use to which most of the world's molybdenum is put is in form of ferro-molybdenum, the preparation of special varieties of steel. The result of the addition of a small portion of metallic molybdenum to steel is very similar to that obtained by the use of tungsten. Molybdenum is more potent than tungsten, and only about half as much of the molybdenum is necessary as would be required were tungsten used instead.

Molybdenum steel is used for rifle barrels, propeller shafts, large guns, wire, and particularly for the manufacture of high-speed tools. Molybdenum high-speed steel contains from 8 to 10 per cent molybdenum. When the other elements are present in the right proportion a steel is obtained of great hardness, with the peculiar property of retaining its temper when heated to a high degree, differing in this respect from all carbon steels. Owing to this property it is possible to take extremely heavy cuts at high speed, the tool often being heated through this hard use to a dull red heat without impairing its usefulness.

To prevent the freezing of concentrates which form one of the components of the mixture treated on Dwight-Lloyd sintering machines, a steam-heated covered bin is in use at the Salida plant of the Ohio & Colorado S. & R. Company. The walls of the bin are double and filled with coke. Both entrances are provided with two sets of doors, and a temperature well above the freezing point is easily maintained by the heat from two steam pipes which extend along each side of the bin near the roof. The scheme has proved very successful, and involves little expense other than cost of construction.

Metallurgy in British Columbia.

By E. Jacobs.

The chronology of metallurgy in British Columbia in 1911 records only a few items of progress and achievement. The Dwight-Lloyd system of sinter-roasting was installed at the Trail smelter of the Consolidated Mining & Smelting Company of Canada, as recorded and described in Metallurgical and Chemical Engineering in August, 1911, page 405. Later information is to the effect that the plant is successfully roasting copper concentrates, but that similar success has not resulted in treating lead-zinc ores, the latter frequently requiring a second treatment.

The Elmore oil-vacuum process was experimented with at the copper concentrator of the Britannia Mining and Smelting Co. Graded crushing and concentrating had been developed to a very satisfactory point at this plant, resulting in a recovery of 80 per cent, due largely to hand-sorting and coarse jigging. Loss in slime, however, had been excessive, and it was in an effort to overcome this loss that the Elmore process was tried. The results obtained from a standard-size unit show a high recovery from fine ore and slime, which will materially increase the present total recovery of 80 per cent. The product will be nearly neutral as far as smelting is concerned.

The French Zinc Process.

Mr. A. Gordon French, a metallurgical chemist who has previously experimented with the reduction of lead-zinc ores at Nelson, B. C., has patented a process which is designed to extract and recover the zinc from such ores as the lead-zinc ores of the Slocan district, British Columbia, leaving a residue containing the silver, lead, iron and gangue to be smelted as a lead ore free from zinc. The advantages claimed for the process are:

1. The recovery of zinc in metallic form.

2. By the removal of the zinc from the original ore, the residue becomes more desirable as a smelting ore, and is higher in grade by reason of the concentration caused by the removal of the zinc.

3. The silver actually occurring in the blende would remain in the residue and be recovered by smelting, whereas it would be lost if the blende were to be removed from the ore mechanically.

The ores experimented on have been concentrates containing galena, blende, pyrite, iron carbonate, gangue and a small percentage of manganese. The ore is crushed to 10-mesh size and roasted to a "dead" roast, converting the sulphides to oxides and some sulphate. While the roasted ore is still in the furnace, a small percentage of nitre-cake is added and thoroughly mixed, being still subjected to the heat of the furnace. The oxides are thus almost completely converted to sulphates.

When the mass has cooled it is leached with water to which some nitre-cake has been added, and the sulphates of zinc and manganese dissolved, together with sulphate of soda. The sulphate of lead is not soluble, and the silver can be rendered insoluble, both remaining with the gangue in the tank. It is claimed by the inventor that sulphate of iron is not dissolved until all the zinc is in solution, and that if the leaching is stopped before the zinc is entirely dissolved no iron will appear in solution.

The filtrate, containing sulphates of zinc, manganese and soda, is then electrolyzed by a direct-current of low voltage, using lead anodes and zinc-sheet cathodes. Zinc is deposited on the cathodes until the desired thickness is attained, when the sheets are removed and stripped, and the zinc melted into bars. Manganese precipitates on the anode as the black oxide, which is brushed off occasionally and accumulates in the bottom of the tank. In practice the circulation of the electrolyte through the leaching tank and electrolytic cell is continuous.

The experimental plant at Nelson has a capacity of only 500 to 1000 pounds of ore. It consists of a roasting furnace with a hearth area of 5 ft. by 20 ft., leaching tank, electrolytic cell, and two solution storage tanks. The upper 15 ft. of the roaster hearth is inclined at an angle of 10 deg., the lower 5 ft. being level.

Stamp Milling and Cyaniding.

The Hedley Gold Mining Co. mines and mills an auriferous arsenopyrite, in which gold is practically the only metal of value. During 1911 the mill treated approximately 57,000 tons of ore of an average value of $12.10 per ton, recovering 92 per cent, or $11.13 per ton. This estimate may be altered slightly by the official figures, but is approximately correct. In comparison with the preceding year the recovery for 1911 was 4 cents per ton higher.

The system of treatment is as follows: The ore is crushed through 14-mesh screen by forty 1050-pound stamps dropping 7¼ inches, 99 times per minute. No gold is recovered by amalgamation, and the pulp is immediately sized through Bunker Hill screens fitted with 60-mesh wire cloth. The screen oversize is concentrated on corrugated-belt Frue vanners, the vanner tailings being reground in a Gates tube mill fitted with Montana-Tonopah lining. The screen undersize is combined with the tube mill product, and the whole is then classsified into sand and slime. The sand is concentrated on smooth-belt vanners and the slime on Deister slime tables. All concentrates, amounting to about 300 tons per month, are sent to the smelter at Tacoma, Wash.

The sand and slime tailings are separately treated by cyanidation. The sand, which is all finer than 60 mesh, is leached for 20 days. The slime is mechanically agitated and allowed to settle. As much clear solution as possible is decanted, and the residue filtered in Oliver filters. The combined gold solutions from leaching and filtering are then precipitated by zinc dust in two Merrill presses, standard 36-in. frame, with 20 and 10 leaves, respectively.

The Motherlode Sheep Creek Mining Co. has recently constructed a 10-stamp cyanide mill, which was expected to be in operation about the first of this year. The best talent available has been employed in designing this mill, with a view to making it thoroughly representative of modern cyanide practice. The mill building is 187 ft. long by 87 ft. wide. The stamps weigh 1250 lbs. each. After crushing, the pulp will be classified in cones, the underflow being reground in a tube mill to pass a 200-mesh screen. The classifier overflow will be combined with the tube mill product, and passed over silver-plated amalgamating plates. Following this the pulp will be thickened in Dorr thickeners, the clear overflow being returned to the battery storage tank. The thickened pulp will be agitated in Pachuca tanks with cyanide solution, again thickened in a Dorr thickener and finally filtered in Merrill slime presses. The cyanide solutions from the Dorr thickener and Merrill presses will be clarified, precipitated with zinc dust and passed through a Merrill precipitating press having a capacity for one month's run.

The gold precipitate will be dried, ground, fluxed with soda, borax and litharge, briquetted, and cupelled to high-grade bullion. Amalgam from the plates will be retorted and melted in the usual manner.

The mill is to be operated by water power. Water from two creeks is conducted through red fir pipe lines, 2100 and 4500 ft. long, respectively, and thence through one 7000-ft. steel pipe line, graded from 16 to 14 inches. The effective head at the mill is 600 ft.

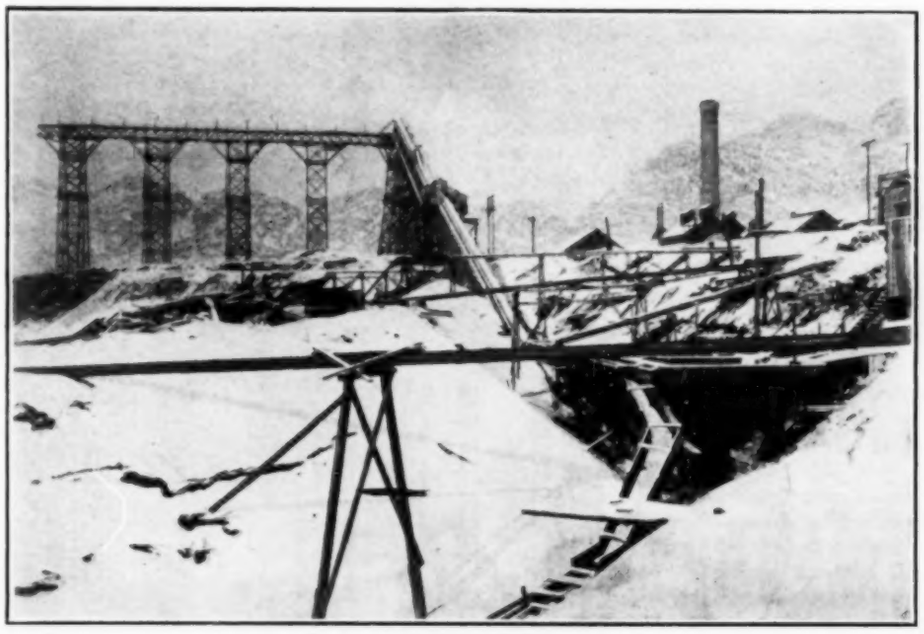
Copper Smelting.

In his last annual report for the fiscal year ended June 30, 1911, Mr. Jay P. Graves, vice-president of the Granby Consolidated M. S. & P. Co., made the following reference to cost of mining and smelting: "Notwithstanding the lower tonnage shipped and the disadvantages under which it was mined by starting and closing the mines at various periods, the cost of mining was only one cent per ton greater than in the previous

year, while the cost of smelting was reduced three cents per ton. I consider this most excellent work in view of the conditions which prevailed at both mines and smelter. I believe it safe to say that the conditions at the mines and smelter are now such that when we are able to operate at full capacity much better results will be achieved and lower costs secured." The tonnage for the fiscal years referred to by Mr. Graves was 950,503 tons for last year, and 1,175,548 tons for the year preceding. The lower costs applied to a tonnage reduced in quantity by 19 per cent.

Conditions during the greater part of the calendar year 1911 were unfavorable to economical work, for a strike of coal mine employees cut off the local supply of coke; and although coke was imported from Pennsylvania for a time, the cost was prohibitory in smelting the characteristic low-grade ores from the mines of the Granby company. As a result, operations have been suspended until local supplies of coke are again available. The labor trouble had a disastrous effect on the production of copper by the Granby, the output for the year being only 11,000,000 lbs. as compared with 20,000,000 in 1910.

The British Columbia Copper Co. operated its mines and smelter throughout the year, notwithstanding the serious disadvantage of the high cost of Pennsylvania coke. The tonnage of ore smelted at Greenwood was about 580,000 tons, from which was recovered 29,600 oz. gold, 127,000 oz. silver, and 9,650,000 lb. copper. Compared with 1910 these figures show an increase in tonnage smelted of 27 per cent, and in copper produced of 31 per cent. The cost of smelting this year will be higher than usual, and will not compare favorably with the cost in former years. The cost of producing and marketing refined copper, after crediting the value of gold and silver recovered, has formerly been as follows: For the fiscal year ended November 30, 1908, 9.996 cents; 1909, 9.829 cents; 1910, 9.048 cents. Further reductions may be expected in 1912 if conditions continue normal.



SLAG DISPOSAL AT GRANBY SMELTER, GRAND FORKS.

New Slag Disposal System.

The excessive cost of continuing the hot-slag haulage system at the Granby smelter at Grand Forks has caused the management to devise new means of slag disposal. The general plan was described in METALLURGICAL AND CHEMICAL ENGINEERING, August, 1911, page 405, but the scheme will be better understood by reference to the accompanying photograph.

Central storage bins have been built below the level of the present slag dump, and to these the granulated slag will be sluiced in flumes. After having been dewatered the slag will be conveyed by belt up an inclined trestle, and discharged by a movable distributor. The space under the incline will be filled first, and later the level trestle will be used as a dumping point. An extension belt can be used for dumping beyond the end of the level trestle when the ground beneath it is filled. It is expected that the system will provide for the disposal of from six to ten million tons of slag, and if its operation proves successful all of the slag from eight blast furnaces will be disposed of in this way.

The Magnetic Properities of Some Nickel Steels

Messrs. E. Colver-Glauert and Seigfried Hilpert (*Journal*, Iron and Steel Inst., 1911, pages 375-411) have investigated alloys of iron with 5.86, 24.32 and 32.9 per cent of nickel by a magnetometric method after slowly cooling from 1250° C., after quenching from 1240° C., 900° C. and 600° C., and after cooling to — 50° C., — 100° C. and — 180° C. The 5 per cent steel is not affected by quenching from 600° nor by cooling, but by quenching from 900° is rendered martensitic and has its coercive force considerably augmented; when quenched from 1240° it becomes only partly martensitic and magnetically softer. The 25 per cent steel is non-magnetic under stable conditions, but at low temperature becomes magnetic without exhibition of any definite critical point; and when quenched at 1240° is equally magnetic at — 180° as when slowly cooled. The authors suggest that at high temperatures there may be formation of a highly magnetic substance dissociating between 900° and 600°, but reforming on further slow cooling. When quenched from 600° the structure is similar to that of natural meteoric irons, and at low temperatures approximates to that of quenched high-carbon steels. The 33 per cent steel is but slightly affected by quenching, and undergoes no change when cooled below 0° C. It has a polyhedral structure, but etching with sulphurous acid brings out an apparently duplex structure similar to that of the 25 per cent steel.

Steel Pipe Contract.—Messrs. J. G. White & Company, Inc., of New York and San Francisco, have just purchased 124 miles of 12-in. steel pipe to be used by them in building a natural-gas line for the Midway Gas Company in California. The pipe will weigh approximately 11,000 tons, and with transportation, will cost approximately $600,000. The particularly interesting feature of his contract is that quotations were asked from British, German and French manufacturers, and the best foreign price was that of a British firm, which, exclusive of duty and freight, was approximately double that at which the contract was placed with the National Tube Company, a subsidiary of the United States Steel Corporation. This indicates the remarkable resources of the United States for cheap production of steel.

The American Museum of Safety has awarded the Travelers' Insurance Medal to the Pennsylvania Railroad Company, the Scientific American Medal to the Norton Company, and the Seaman Medal to Dr. Doty.

Recent Improvements in Filtration Methods*

BY ERNEST J. SWEETLAND.

Probably the simplest method of filtration is that of pouring the liquid to be filtered into a suspended bag and catching the solid matter in the bag while the filtrate is caught in a receptacle below. This method was conceived in the kitchen and has been used by housewives for generations. Although it seems primitive, it is the method at present employed in most cane sugar refineries. The great disadvantage of bag filtration is that the bags have to be turned inside out to be cleaned.

The method of filtering through bags inwardly, that is, passing the liquid from the outside of the bag and draining the filtrate from the interior, has also been employed in sugar-house work to a limited extent. By this method the solids are deposited on the outside of the bag, and it is, therefore, more easily cleaned. In this type the usual arrangement is to enclose a corrugated plate or grid in the flattened bag to prevent it collapsing under external pressure, and a series of bags so arranged are enclosed in a box capable of sustaining a moderate pressure.

A flat filter bag provided with means to prevent it from collapsing when subjected to external pressure, and having a suitable drainage outlet for filtered liquor, constitutes a filter leaf. The different methods by which filter leaves may be constructed are too numerous to be described in detail here.[1]

The first large leaf filter installations were introduced in the cyanide process, and were of the vacuum type.

In the vacuum leaf-filter the leaves are arranged in groups and submerged in the liquid to be filtered, and suction applied to the interior of the leaves. The partial vacuum formed draws the filtrate into the leaves, whence it drains to the vacuum receiver, or, in the absence of a receiver, it is drawn directly through the vacuum pump.

Vacuum leaf-filters are divided into two classes: namely, the movable leaf type and the stationary leaf type. In the former (Fig. 1) the "cake" of residue is first deposited on the surface of the leaf to a thickness of one-half to three-quarters of an inch. The sludge[2] is then withdrawn from the filter box, and wash water is admitted to take its place. During the time the change from sludge to wash water is taking place vacuum is maintained in the leaves to prevent the cakes from dropping off. The cakes will not fall as long as the vacuum is continued. As soon as the leaves are submerged in the wash water, washing commences, and is continued until the valuable solution in the cake has been displaced with water. When this is done the suction is discontinued.

The next step is to dislodge the cakes from the filter leaves and discharge them. This is done by simply admitting compressed air into the leaves, which bulges the cloth slightly and the cakes immediately fall to the bottom of the hopper.

When the cakes have fallen the surplus water in the box is decanted off for re-use, and the pasty mass of cake is discharged through a large valve at the bottom of the hopper.

The operation of the movable leaf type is similar to that of the stationary type, except that, instead of the sludge and wash water being transferred, the group of leaves is transferred by a travelling crane from a sludge tank to a wash water tank.

The requirements of a filter in the cyanide process are most exacting. When it is noted that a moderate-sized plant will handle 300 or 400 tons of ore residue, or slime, per 24 hours; that the cost of filtering must be well under 10 cents per ton of dry ore filtered, and that the element in solution to be recovered by washing is in many cases gold, worth $20.67 per ounce, the importance of the filter is realized.

In the case of a cyanide filter working on a gold ore, in good practice the amount of dissolved gold which escapes recovery will range from one two-hundredth to one five-hundredth of an ounce per ton of dry residue, or say about one grain per ton.

This splendid washing efficiency is due to what I shall take the liberty of calling "direct-contact washing." The cake is deposited in an even layer on the leaf, and, when submerged, is in direct contact with the wash water. The cake has been deposited in a natural unrestricted manner without packing or crowding, and with an even pressure in all directions. A cake deposited in this manner will, if all conditions are suited to the material in hand, be of even thickness throughout and of even density, but if during the cake-forming some disturbing in-

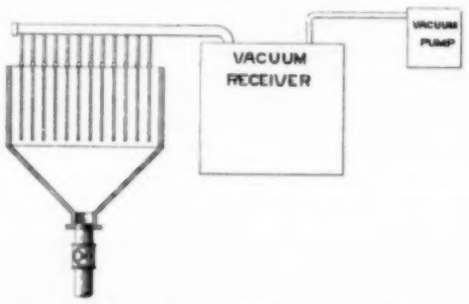


FIG. 1.—MOVABLE-LEAF TYPE OF VACUUM FILTER.

fluence enters, which tends to cause the cake to vary in thickness, the density, or perviousness, of the cake will automatically adjust itself to suit the varying conditions, which insures even washing.

The rate of percolation through the cake is governed by the resistance offered by the cake and the pressure of the liquid against the cake.

Other conditions being equal, two cakes of the same thickness and of the same degree of porosity will offer equal re-

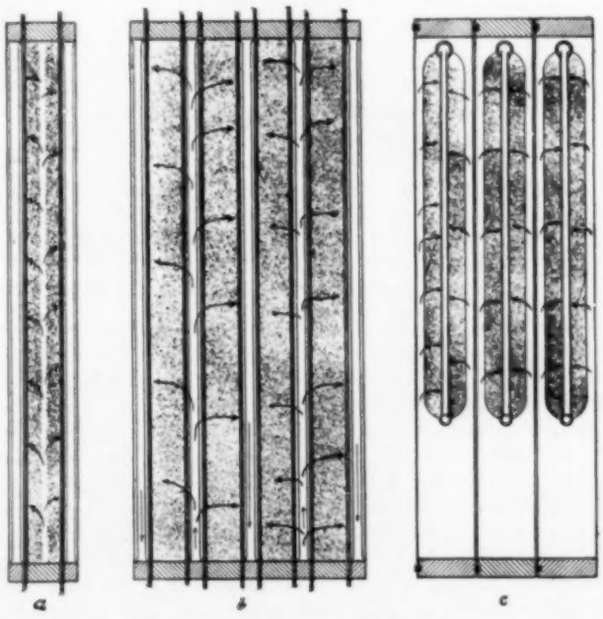


FIG. 2.—PLATE AND FRAME FILTER PRESS.

sistance to percolation, and therefore filter at equal rates per unit of area.

If two cakes vary in resistance they must vary in thickness in order to be equally washed in a given time.

To properly consider these statements it is necessary to consider the resistance of the filter cloth as well as that of the cake. That is, the resistance per square foot of cake is equal to the resistance of 1 sq. ft. of cake plus the resistance of the square foot of cloth underlying it.

*Presented at the Meeting of the American Chemical Society, New York, Jan. 5, 1912.

[1]Several small leaves of simple construction were exhibited at the meeting for examination.

[2]The term "sludge" as here used refers to a fluid mixture of liquid and solid matter to be filtered.

For example, suppose that for some reason a portion of the cloth of a filter leaf has become partially obstructed and offers more resistance than the rest of the leaf. While cake forming is in progress the cake formed on this partially obstructed spot will be thinner than that in other places. Now when the cake is submerged in wash water the resistance which limited the thickness of the cake in this spot again comes into play and limits the amount of wash water which passes through it. In this manner the thin cake receives an amount of wash water proportionate in its volume.

Before proceeding let us compare the cake forming and washing in a common plate and frame filter press with the

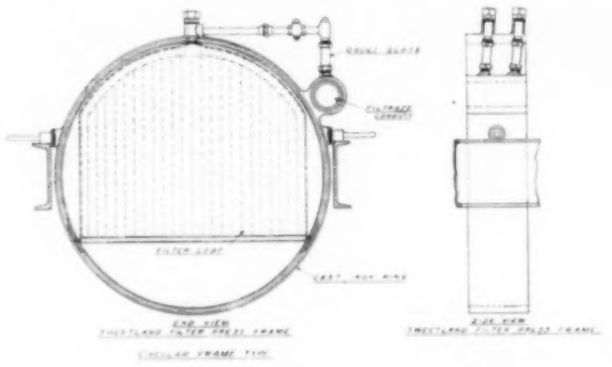


FIG. 3.—DETAILS OF SWEETLAND FILTER PRESS FRAME.

same in leaf filters. In forming a filter cake with any material there is a certain point where the rate of filtration begins to drop off very rapidly due to the resistance offered by the cake. When this decrease has been noted, the cake has reached the economical limit of thickness, and to proceed farther is a waste of time and power. For instance, it has been noted that with certain colloidal materials a cake of ½ in. can be formed in about 30 minutes, but at this point filtration becomes so slow that to increase this cake to 1 in. in thickness would take several hours. Obviously this would not be economical.

In a plate and frame press each wall of the frame cell is a filtering wall, and the cake builds up on each wall until the two adjacent cakes finally join together to form a single cake filling the entire cell. In Fig. 2, "*a*" shows the cake partly formed, and the arrows indicate flow in both directions while filling the press. In "*b*" the cells are shown filled, the arrows indicating direction of flow of wash water; "*c*" shows cakes on filter leaves and the arrows indicate the direction of flow both while cake forming and washing.

Now to get the maximum cake-forming capacity from the filter press, the cake formed on each cloth must be up to the economical limit of thickness. This is all right if washing is not contemplated; but if the cake is to be washed we find that wash water has to be forced through a cake twice as thick as it should be.

If to overcome this objection the thickness of frame be reduced to give a cake of proper thickness for washing, then the capacity of the filter press for cake forming is greatly reduced. In all cases the frame must be solidly filled with cake, as otherwise the line of junction between the cakes formed on opposite surfaces of the cell will be soft and make good washing impossible. Furthermore, if the solid matter in hand varies in structure, some of it being granular while the rest is colloidal, the granular particles will tend to settle to the bottom of the filter press frames, making the lower portion of the cake more porous than the upper portion, and when washing is in progress the bulk of the wash water passes through the lower portion of the cake, leaving the upper part imperfectly washed.

Again, some cakes tend to shrink during washing, and shrink away from the rigid walls of the frames, leaving channels through which a portion of the wash water passes, unduly increasing the volume of wash water, and impairing the efficiency of the wash.

In leaf filters the maximum economical thickness of cake can be formed, because the cake is washed exactly as it was formed, a double thickness of cake never has to be washed. Then too, in the leaf filter, the direction of flow during washing is the same as during cake forming, while in the plate and frame press one-half of the cake is washed in the opposite direction to which it was formed against the grain, so to speak, and this tends to disturb the natural arrangement of the particles.

If the texture of the cake-forming material in which a filter leaf is operating varies, and the granular portion settles toward the bottom, the thickness of the cake will vary, and it will be thicker at the bottom than at the top, so that the granular portion which admits of the more rapid passage of wash water is thicker than the less porous portion, and really *requires* more washing.

What are technically known as vacuum filters are, in reality, pressure filters, operated by atmospheric pressure. Obviously in an open filter of this type the maximum pressure that can be brought to bear under ideal conditions would be 14.7 lb. per

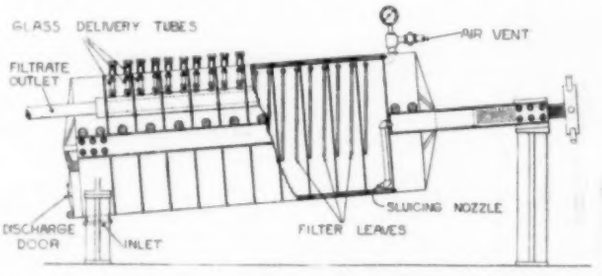


FIG. 4.—SWEETLAND FILTER PRESS SHOWN PARTIALLY IN SECTION.

square inch. Under practical conditions the vacuum maintained is usually about 22 in. or the equivalent of 11 lb. pressure per square inch. Since the rate of filtration is in proportion to the pressure, the low pressure available in vacuum filtration makes the size of installation necessary for a given capacity very large. This gives rise to a number of objections, namely:

Large initial cost.

Large floor space and head room required.

Excessive power consumption.

High cost of maintenance.

In addition to these, vacuum filters are entirely unavailable for filtering hot solutions.

The logical means of overcoming the objections cited is to enclose the filter leaves in a chamber so that greater pressure can be used and thus greatly reduce the size of the installation, since the principles governing leaf filtration apply regardless of whether suction or external pressure is used.

The difference betwen vacuum and pressure filters has been aptly explained by saying that in the former the liquid is pulled through the cloth while in the latter it is pushed through.

The number of mechanical arrangements by which pressure leaf filters may be constructed are many. Of these, three different types have been in operation on a large scale for some time. There are the Kelly, the Burt, and the Sweetland filters.

The Kelly filter comprises a plurality of leaves mounted on the door of a steel shell and provided with rollers by means of which the groups of leaves may be rolled into the steel shell and the door bolted in place. When ready for discharge the door is unfastened and the leaves rolled out of the shell.

The Burt filter comprises an inclined steel shell with vertical leaves suspended at intervals throughout the length of the shell. The cakes are discharged through a door in the lower end of the shell.

In designing the Sweetland filter I endeavored to keep in

view the great importance of easy accessibility of all the parts for examination or renewal, and at the same time to provide a construction of such flexibility as to meet the many and varied demands of the chemical and metallurgical industries. In general appearance the Sweetland filter somewhat resembles the standard types of plate and frame filter press, that is, it comprises a series of frames resting upon a pair of side bars, and an end piece, or head, forms a closure for each end. Each frame carries an inserted gasket of rubber or other suitable material, and the frames are clamped together to form a watertight chamber by means of a heavy screw bearing against the movable head.

Each frame carries a removable leaf, and in the usual construction a space is left between the bottom of the leaf and the lower wall of the frame.

The operation is as follows: The liquid to be filtered is admitted to the chamber through an inlet at the bottom; while filling, the enclosed air escapes through a valve at the top. When the air escape valve is closed the pressure increases within the chamber and filtration begins. When the cake has formed to a suitable thickness the source of supply is shut off and the excess unfiltered liquid is withdrawn from the chamber.

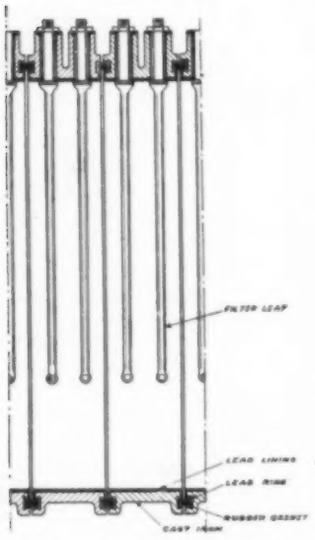


FIG. 5.—SECTION OF LEAD-LINED FILTER.

In most cases the cake will adhere to the leaf without assistance, but in case the material in hand shows a tendency to drop off the leaves the cakes are held in place by vacuum applied to the interior of the leaves. The excess sludge having been removed, wash water is admitted to the chamber under pressure, the enclosed air being allowed to escape as before. The wash water percolates through the cakes and displaces the soluble salts. This done the excess wash water is withdrawn for future use.

The cakes are now to be discharged. If wet discharging is permissible, water under pressure is turned through the discharge nozzles at the upper end of the press. The cakes are then forced off of the filter leaves with compressed air, and as they fall to the bottom they are rapidly sluiced out through the discharge door in the lower head of the press.

If it is desired to remove the cakes as dry as possible, they are caused to drop into a tray which is inserted into the space in the bottom of the press, or else they are allowed to drop into the space below the leaves and are removed with a hoe or scraper.

If the Sweetland filter is used to clarify a solution containing but a small percentage of solids, the space in the bottom of the press offers a material advantage, for in this space accumulated solids may be stored without obstruction to the filter surface. When the press is in operation in this manner it is allowed to run until accumulated solids on the leaves begin to materially decrease the rate of flow. When this occurs a puff of compressed air is admitted to the interior of the leaves, and the rush of air through the pores of the cloth in the contrary direction to filtration disengages the solids from the filter cloth, and the thin cakes fall to the bottom of the press, to lie there until sufficient has accumulated to justify opening the discharge door and flushing out the press.

The sectional construction described permits of a great many modifications. Lead lined presses of this type have been built for acid solutions, the sheet lead lining being joined by fusion to lead rings which are cast into the edges of the cast iron frames. (Fig. 5.)

The frames are made of wood for such materials as make the use of metal impracticable, and in such presses the head pieces are made of cast iron with wooden linings, and a wooden tray may be used to receive the cakes when discharging. (Fig. 6.)

Bronze presses of the Sweetland type are built, and have the particular advantage of being much lighter than plate and frame presses, since the filter leaf takes the place of the heavy plate.

These presses have also been built with steam spaces in the frames for maintaining the heat of the liquor being filtered. These spaces do not in any way interfere with the sectional construction.

The possibilities of leaf filtration are broadening every day. It has recently been demonstrated that, in refining oils and fats with Fuller's earth, the amount of oil left in the residue can be greatly reduced by the construction described, which means a notable saving.

The time is near at hand when bag filters in cane sugar refineries will be displaced by leaf filters of the pressure type,

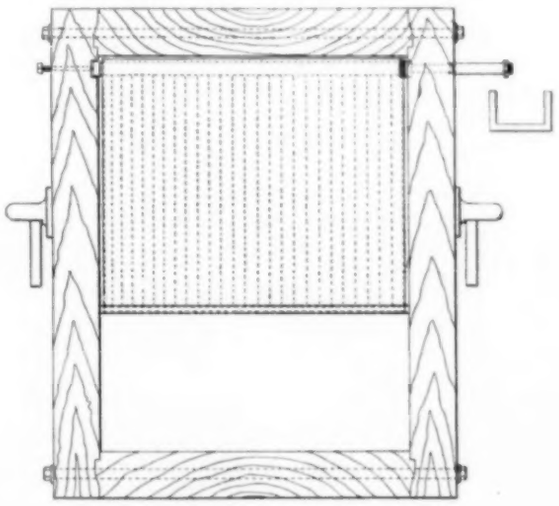


FIG. 6.—WOOD FILTER PRESS FRAME.

for not only is cleaning of the leaves made almost automatic by reversal of current through the cloth, coupled with suitable spraying devices, but the filter area required for a given capacity will be greatly reduced.

Experience has shown that filter cloth made into leaves lasts longer than the same cloth used in plate and frame presses, because on the latter the cloth is subject to handling, scraping and other mechanical injury from being squeezed between the units of the filter press.

The filtering requirements of the chemical industry are so many and varied that it would be absurd to blindly advocate any specific construction as a cure for all filtering evils. Each problem must be approached with care and each installation properly designed to suit the needs of the material in hand, and when this is done higher efficiency and lower filtration costs will be realized.[8]

The Granby copper smelter at Grand Forks, B. C., has resumed operations after a suspension of several months due to labor troubles at the coal mines. Coke was imported from Pennsylvania for a time, but this proved too costly, and operations were suspended until normal labor conditions were obtained in the province.

[8]All important features of the Sweetland Filter Press are protected by a series of patents owned by the Sweetland Filter Press Company, New York.

Recent Metallurgical Patents

Gold and Silver.

Clancy Process of Treating Gold Ores.—Mr. John C. CLANCY, of New York, has added another to his long list of recent patents for the treatment of gold ores by the use of amide compounds. In the present instance Mr. Clancy states that electrolysis can be dispensed with, and that an amidine compound, such as calcium cyanimide, forms with a cyanogen-bearing solution an active solvent for the precious metals. Alkaline ferro or ferrocyanides, soluble prussian or insoluble prussiates, are included in the list of cyanogen-bearing compounds which act thus with calcium cyanimide. The process is applicable to the treatment of old dumps from former cyanide treatment, for in these accumulations there exists a large proportion of Prussian blue, which when treated with alkali becomes substantially alkaline ferro or ferricyanide, or soluble prussiates. Low-grade ores also are amenable to this process, for it makes use of cheap materials.

For use on old-dump material Mr. Clancy gives the following procedure: 2000 lb. of water containing 1 lb. of cyanimide and 1 to 5 lb. of lime give results equivalent to the use of straight cyanide solution when used in the proportion of two or three parts of solution to one part of ore.

On low-grade ore the solution is made up as follows: 2000 lb. of water, 1 lb. of alkaline ferrocyanide and 1 lb. of lime. The proportions of solution to ore are the same as indicated above, and the time of extraction is eight to ten hours.

Zinc and Lead.

Treatment of Complex Ores.—Among those investigators who have given attention to the chemical treatment of mixed sulphide ores, Mr. EDGAR A. ASHCROFT, of Sogn, Norway, is well known for his proposed chlorination methods. Recently four interesting patents have been granted to Mr. Ashcroft, based on improvements in the treatment of mixed lead-zinc ores or concentrates.

The two principal products obtained from concentrating mills are (*a*) zinc concentrates containing upward of 40 per cent zinc, under 12 per cent lead and some silver; and (*b*) lead concentrates containing upward of 50 per cent lead, under 12 per cent zinc and some silver. In smaller quantities there is produced an intermediate product (*c*) such as slimes and middlings of varying composition. Zinc and lead smelting are respectively used for the reduction of these zinc and lead concentrates, but in the smelting processes the metals unfavorable to each are either wholly lost or imperfectly recovered at further expense. The product (*c*) is smelted only in small admixtures to the main products, or further separated into products resembling either (*a*) or (*b*). Mr. Ashcroft's patents refer, first, to the special treatment of (*a*) for the removal of the lead; second, to the treatment of (*b*) for the removal of the lead; and, third, to the treatment of the zinc residue from (*a*) and (*b*) for the recovery of the zinc.

The steps in the removal of lead and silver from zinc concentrate (product *a*) are briefly, as follows: Treatment of the crude concentrate with fused chloride of zinc (or preferably a mixture of the chlorides of zinc and sodium in molecular proportions, on account of the lower specific gravity and greater stability of this mixture), whereby reactions occur between the sulphides of lead, silver, antimony, iron, and manganese, and the zinc chloride, forming chlorides of the metals named and sulphide of zinc. The chlorides are then removed from the zinc sulphide residue, which is washed to remove any remaining soluble chlorides. The melt containing the lead and other metals is then treated for the regeneration of zinc chloride and the recovery of the metals.

Fig. 1 shows one method of carrying the invention into effect. The treatment is carried out at a temperature under 500 deg. C., in kettles *A* mounted on trunnions *B* and provided with an agitating apparatus B^1, and loops *C* whereby the pots can be lifted by cranes. Each pot is provided with a furnace *D*. Ore is introduced into the lowest pot as at F^1 and the pots are successively moved upward after a suitable period of treatment. The fused zinc chloride is introduced into the upper pot as at G^1, and the fused mixed chlorides after the reaction has taken place in the upper pot is poured into the second pot and subsequently into the lowest pot. In each pot there are three layers; molten lead *E* at the bottom which is designed

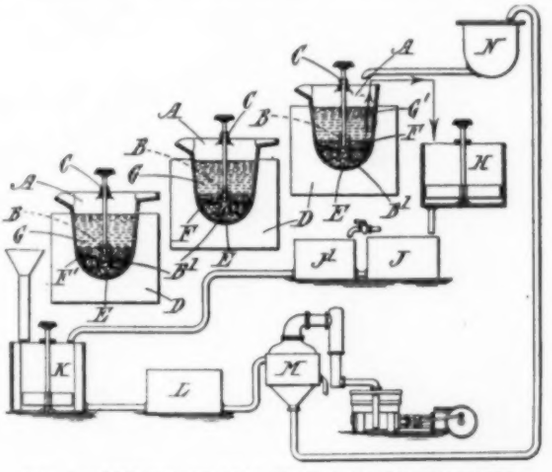


FIG. 1.—REMOVAL OF LEAD FROM ZINC CONCENTRATES.

to dissolve silver, the zinc ore of concentrate *F*, and the fused melt *G* consisting of zinc-sodium chlorides. The latter has a low specific gravity, and as the lead chloride dissolves in it the specific gravity is not greatly raised so that the melt floats on top. When the fused melt has been poured off the uppermost pot into the second, the lead bath (containing silver) is run off into a storage pot whence it can be drawn for further use or sent to a furnace for cupellation. The residue, consisting of heavy sulphide of zinc with some occluded chlorides of zinc and lead, is allowed to cool to about 250 deg. C., balled up by stirring and introduced into an agitation vessel *H* with hot water. The mass disintegrates, with solution of the soluble chlorides. The mixture is passed to the filter *J* from which the solution of chlorides is removed to the tank J^1 to crystallize out the lead chloride. The fused melt from the bottom pot may be poured directly into water in an agitating vessel *K*, from which the whole contents are discharged into a filter *L* where any residue is removed from the chloride solution.

The treatment of the melt for lead recovery permits of several alternative methods. The melt will usually contain suspended finely divided zinc sulphide formed by the reaction between the zinc chloride and galena, and this suspended zinc sulphide will not settle out of the melt with the same facility as will the zinc sulphide concentrate. One method of treating the melt, therefore, consists in introducing it into water, with or without the addition of a small quantity of HCl or H_2SO_4, so that the lead chloride and suspended zinc sulphide react to form lead sulphide or sulphate, and zinc chloride. Or, the lead chloride may be separated by crystallization and treated in the same manner with finely divided zinc sulphide. Again, the separated melt, containing zinc and other metallic chlorides, may be electrolyzed for the recovery of lead. Three alternative methods are available: first, the simple electrolysis of $PbCl_2$ whereby lead and chlorine are produced, the latter being used to chloridize zinc sulphide according to a process of Swinburne and Ashcroft; second, $PbCl_2$ is electrolyzed at a low temperature in the presence of suspended zinc sulphide whereby lead and sulphur chloride are obtained, the latter being used to chloridize zinc sulphide; third, the fused melt or recovered lead chloride is mixed in molecular proportions with the purest zinc sulphide available and electrolyzed at a high temperature, whereby lead and sulphur are obtained. The zinc chloride is

regenerated in each case for further use in the process. Electrolysis when sulphides are present in the bath is extremely economical of energy and apparatus. Anodes may be of carbon, and cathodes of molten lead, and the current required need not exceed a pressure of two volts with a current density of 500-1000 amp per square foot of anode surface.

As an instance of the working of this invention the inventor cites the following: Taking an ore assaying 40.2 per cent Zn, 10.6 per cent Pb, 8.5 per cent Fe, 9 per cent insoluble, 22 per cent S, and 16.7 oz. Ag per ton, he obtained a solid residue of unchanged zinc sulphide weighing when washed and dried 78 per cent to 82 per cent, assaying 50.6 per cent Zn, 0 per cent to 1 per cent Pb, 8 per cent Fe, 8.5 per cent insoluble and 0.25 oz. Ag per ton. The lead bath contained nearly all the silver content of the original ore. In the second stage of the process metallic lead, quite pure, and chlorine gas were obtained. When electrolysis was not used, the melt being dissolved in water with suspended zinc sulphide present, there was obtained a precipitate of lead sulphide or sulphate with some fine gangue, assaying about half gangue and half lead salt. Thus all the zinc is accounted for in one product, and all the lead in either of two other products. (1,011,897, Dec. 19, 1911.)

In case (*b*) mentioned before (lead concentrate containing small quantity of zinc), the proportion of lead sulphide is so high that it may be electrolyzed direct to lead and sulphur or chloride of sulphur, by so treating the ore as to dissolve the lead sulphide in lead chloride in a fused state, forming what the inventor terms lead chlorosulphide which is then electrolyzed. Thus the ore may be charged into a bath of fused lead chloride, where, after agitating with molten lead to extract the silver as before, it is allowed to stand some time. Owing

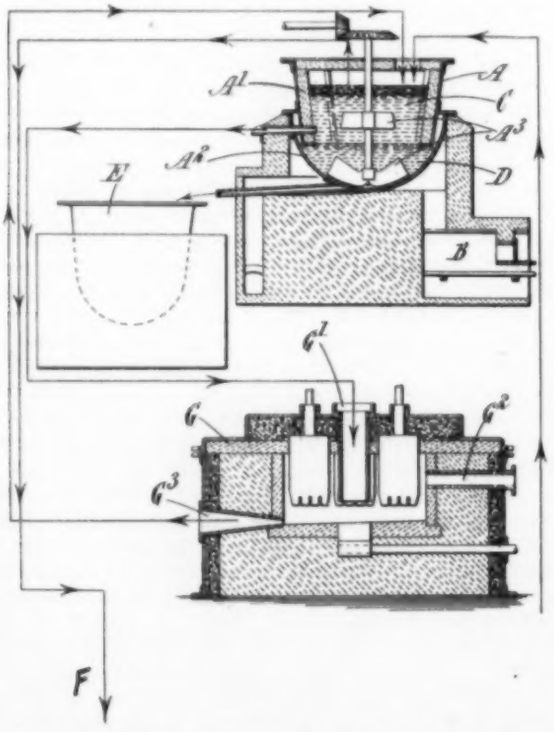


FIG. 2.—TREATMENT OF LEAD CONCENTRATE CONTAINING SMALL QUANTITY OF ZINC SULPHIDE.

to the high specific gravity of the melt, the gangue and zinc sulphide will float, leaving a clear melt of lead chlorosulphide below, which is tapped off and electrolyzed until all the sulphur is discharged and the corresponding lead recovered as pure metal. The lead chloride remaining from the electrolysis is then returned to the cyclic process. The floating matter containing the gangue and zinc sulphide is then suitable for treatment described above for product (*a*), shown in Fig. 1.

Fig. 2 shows the application of the process to lead concentrate containing a small quantity of zinc sulphide. *A* is a mixing pot with furnace *B*. The pot contains molten lead *D* for the recovery of silver, fused lead chloride bath *C* to dissolve lead sulphide, and a floating mass of gangue and zinc chloride. The lead may be tapped into a pot *E*, the lead chlorosulphide to an electrolytic vat at G^1, and the floating mass to the apparatus shown in Fig. 1, which would be placed

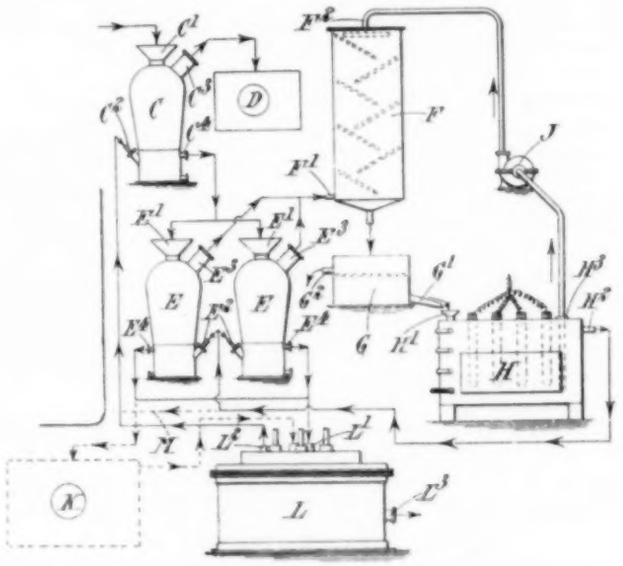


FIG. 3.—APPARATUS FOR CHLORINATION AND ELECTROLYSIS.

at *F* in Fig. 2. In the electrolytic vat the sulphur or chloride of sulphur passes out at G^2 for recovery and use, the reduced lead is removed through G^3, and the lead chloride remaining after electrolysis is complete is returned through the outlet G^1 to the mixing pot *A*. (1,011,898, Dec. 19, 1911.)

The final step in Mr. Ashcroft's invention consists in reducing the clean concentrated zinc residues obtained from the treatment of products (*a*) and (*b*), as described above. The inventor claims to have devised improvements on the method of dry chlorination invented by Swinburne and himself, the chief objection to which was the elimination of the gangue matter and the iron and manganese.

The present chlorine smelting process with electrolysis is carried out substantially as follows: The zinc concentrate is made into a cream with fused chloride of zinc. The cream is treated in a suitable vessel with chlorine or sulphur chloride which is forced in at the bottom of the vessel. At a temperature of 600° C. and upward, which is within the fusing and vaporizing points of zinc chloride, the reaction is most vigorous. The chlorine is rapidly absorbed and sulphur given off, the latter being condensed and saved. As the reaction is exothermic the temperature may be controlled by the rate of admission of the chlorine gas. The treatment is continued until all the sulphides are converted into chlorides, and additional supplies of sulphides may be added to the converter until a suitable quantity of chloride has accumulated. Toward the end of the reaction a little chlorine gas may escape, but this point is readily indicated by the emission of copious fumes of ferric and manganic chlorides. At the end of the reaction, the bath contains fused chlorides of zinc, iron and manganese, the latter two being in the "ous" condition.

The melt is now tapped into secondary converters, and more chlorine gas passed in. The result is that volatile ferric and manganic chlorides are driven off and absorbed in apparatus filled with 10 per cent to 15 per cent NaOH formed in a secondary electrolytic apparatus. The iron and manganese are thus recovered as hydroxides, and the caustic soda converted into sodium chloride, which is returned to the electrolytic ap-

paratus. The resulting "iron free" fused chloride of zinc is then treated by electrolysis for the reduction of zinc and recovery of chlorine.

Fig. 3 represents apparatus for carrying the chloridizing and electrolysis into effect. *C* is the main converter in which the fused sulphide and chloride of zinc is treated with chlorine, which is generated from the primary electrolytic vat *L*. The sulphur given off in this reaction is condensed in *D*. *EE* are secondary converters in which ferric and manganic chlorides are driven off by the addition of chlorine derived from a secondary electrolytic cell *H*, from which, also, is derived the NaOH solution used to absorb the iron and manganese chlorides in the absorbing apparatus *F*. The "iron free" fused zinc chloride is then electrolyzed in the primary cell *L*, or, if lead and silver have not been removed by the process described before, they are removed in *K* before electrolysis. *G* represents a filtering mechanism for the separation of iron and manganese hydroxides from sodium chloride solution, the latter being returned to the secondary cell *H*. (1,011,899, Dec. 19, 1911.)

A further method for the electrolysis of sulphides is outlined by Mr. Ashcroft as being an improvement on Swinburne's method, in which the latter electrolyzed sulphides in a bath of fused chlorides with the production of metals and sulphur. The objection to Swinburne's procedure was that the reaction required very high temperatures (about 600-700° C.) and very violent agitation of the melt to prevent settling. Mr Ashcroft proposes to carry on the electrolysis at lower temperatures at which chlorides of sulphur will be given off instead of sulphur, according to the following reactions:

$$MS + 2\,MCl_2 = 3\,M + SCl_4. \quad \text{Temp. } 350^\circ \text{ C.}$$
$$MS + MCl_2 = 2\,M + SCl_2. \quad \text{Temp. } 450^\circ \text{ C.}$$
$$2\,MS + MCl_2 = 3\,M + S_2Cl_2. \quad \text{Temp. } 550^\circ \text{ C.}$$

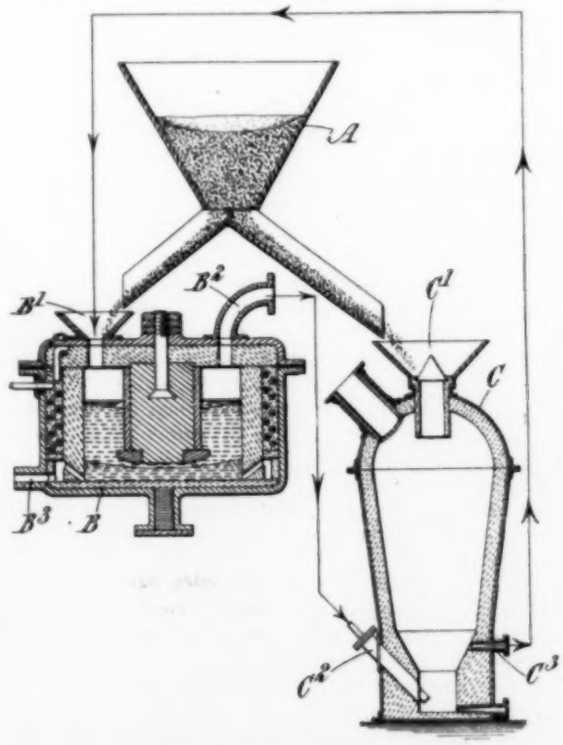


FIG. 4.—SULPHIDE ELECTROLYSIS.

The sulphur chlorides may be condensed and made to react with metal sulphides according to Swinburne and Ashcroft's method, forming sulphur and metal chlorides, the latter being added to the electrolysis bath to compensate for the chlorides decomposed by the above reactions.

When zinc is the metal to be recovered it is necessary first to remove iron, and this may be done by fractional electrolysis, using a cathode of molten lead to alloy the iron. A cathode of molten zinc may then be substituted and the zinc obtained therein. When lead is the metal under recovery it is not necessary first to remove iron as it is maintained in the ferrous state by the reducing action of the sulphides present and so does not interfere with the precipitation of the lead.

At the end of the reaction it may be desirable to separate zinc or lead from the chloride, and for this purpose sodium sulphide may be used, thus:

$$2\,ZnCl_2 + Na_2S = 2\,Zn + SCl_2 + 2\,NaCl.$$

Fig. 4 shows an arrangement for carrying this process into operation. Ore from the bin *A* is fed both to an electrolytic vat *B* and a converter *C*. In *B* the metal is reduced and the chloride of sulphur is conducted into the converter at C^2, where it reacts with ore forming metal chloride and sulphur. (1,011,900, Dec. 19, 1911.)

Synopsis of Metallurgical and Chemical Literature.

Gold and Silver.

Chispas Cyanide Plant, Arizpe, Mexico.—In the Columbia School of Mines *Quarterly*, for November, 1911, Mr. EDWARD L. DUFOURCQ gives details of the construction of a plant to cyanide an ore consisting of clean quartz carrying silver as argentite, polybasite and stephanite, with free gold at the rate of 1 oz. gold to 130 oz. silver per ton. An incomplete analysis of the ore follows: Insoluble, 80.6 per cent; Fe, 2.4; CaO, 1.6; S, 1.6; Sb, 0.3; Zn, trace; Pb and Cu, none. In addition to treating this ore, the plant was designed to handle an accumulation of the old tailings from stamp-amalgamation-concentration work.

Experiments on the accumulated tailings indicated that they would yield a recovery of 93 per cent of the silver and 98 per cent of the gold, with a cyanide consumption of not to exceed 3 lb. per ton, lead acetate 0.2 lb. per ton, and lime 2 lb. per ton. Thirty-six hours' agitation would be required if the tailing were ground to 150-mesh or finer.

The old mill consisted of Blake crusher, 20 stamps, three Wilfley tables and two amalgamating pans. In remodeling the plant for the use of cyanide it was decided to abandon amalgamation, increase the aperture of battery screens, concentrate on tables, and cyanide the table tailings after sliming them in tube mills.

A belt conveyor was installed to carry old tailings back to the mill where it is mixed with current tailing, the mixture being given the following treatment: It is first classified in a Dorr machine, the coarse product from which passes to an Abbe tube mill, 4½ x 20 ft., trunnion bearings, El Oro lining. The pebble charge consists of 16,000 lb. Danish pebbles. Cyanide solution is added with the sand to make a feed of proper consistency. The tube mill discharges into a second Dorr classifier from which the unground sand is returned to the tube. The slime passes to a Dorr thickener, 8 x 24 ft., and thence to any one of six air-agitation tanks, 12 x 36 ft.

The agitators are constructed as follows: Four rings of steel plates form the conical section of the tank, which is 27 ft. high. The top and bottom series of plates are riveted to angle irons at top and bottom of the cylinder. The cone bottom, which has a slope of 60 deg., also is riveted to the lower angle iron. The cone ends in a 10-in. cast-iron T, on one side of which is a blind flange and on the other a 10-in. gate valve. The agitation is accomplished by the Towne method. A central 10-in. pipe is placed in the agitator, reaching nearly to the bottom of the cone, and extending 2 ft. above the top of the tank. It is perforated with rows of four holes, 1½ in. in diameter, the rows being 1 ft. apart except at the upper end of the pipe where, for 2 ft., they are 6 in. apart. Almost at the top level of the tank there are four 2-in. pipes extending outward and spirally curved from the central pipe to the circumference of the tank. Air is admitted through the blind

flange at the cone through a 1½-in. pipe which extends upward into the central tube for a distance of 18 in., terminating in a ball check valve. The tanks are discharged through the 10-in. gate valve at the cone, all tanks being connected with an Aldrich 6 x 7-in. triplex slime pump.

After agitation the tanks are allowed to settle, and about 8 ft. of clear solution may be drawn off to the gold solution storage tanks. The thick pulp is then pumped to a masonry tank 80 ft. above the Burt filter, from which the latter is fed with slime. This arrangement was adopted as preferable to direct filling from the pump, and is expected to provide for quick filtration without the excessive pressure which was developed by the pump when it was run at the speed requisite for rapid filling. A second masonry tank at the same height above the filter contains weak solution for washing the filter cake. Still another tank placed 290 ft. above the filter contains water which develops the hydraulic pressure to operate the filter door.

The gold solution is precipitated with zinc dust, two types of feeders being installed for comparative test. These are the Colbath and the Creston-Colorado types. The Creston-Colorado filter press is used to recover the zinc-gold precipitate. The author expects to publish later a full account of the comparative merits of these zinc dust feeders, also to give working costs at the plant.

Cyanidation of Nicaraguan Gold Ore.—The crude methods and enormous loss involved in the treatment of gold ore in the Pis Pis district on the Atlantic coast of Nicaragua, together with remedies for the existing conditions, are outlined in a paper published in the December *Bulletin* of the A. I. M. E. The author, Mr. Henry B. Kaeding, states that the future metallurgy of these ores depends on chemical, mechanical and economical considerations.

The ores consist of quartz carrying galena, pyrite, marcasite and chalcopyrite, and occasionally hematite, magnetite and shpalerite. Gold is associated with these minerals. Owing to excessive rainfall the ores above the water level are oxidized and leached, and have become highly acid. It has been the custom to crush, grind and amalgamate these ores, cyaniding the sand tailing and allowing the slime to run into the creek. The recovery has averaged probably 57 per cent. Caustic soda has been used to counteract acidity, with the result that iron and aluminium hydroxides have been precipitated and made settling or filtration impossible. As a consequence the opinion has prevailed that these ores cannot be cyanided and filtered. The ores below the water level have been let severely alone.

The author has experimented on all the ores and has found that extraction depends on fine grinding, and that filtration can be accomplished only by a rigid exclusion of sodium hydroxide from the process. A pulp consisting of 1 part of slime and 6 parts of water or cyanide solution will settle in 15 hours so that clear solution can be decanted, leaving a pulp of consistency of 2:1 which can then be filtered by vacuum apparatus. Dead settling in tanks is necessary, as the slightest vibration destroys the settling. The sulphides may be profitably treated with an extraction 90 per cent in 24 hours by grinding so that 90 per cent of the ore passes 200-mesh screen. This was done with a cyanide consumption of 2.9 lb., and with the use of 4 lb. lime per ton of ore.

Under the conditions which exist in this district all machinery would have to be of sectional design to permit of transportation. The author believes, however, that with a plant once erected and with water-power available at practically no expense, ore could be treated at a total cost of from $1.20 to $1.50 per ton. Chemicals cost there as follows: Potassium cyanide, 24 cents; lime, 10 cents, and zinc 14.5 cents per pound. Labor cost is $1.25 per day.

Electrolytic Assay of Gold Solutions.—At the assay office of the Kleinfontein Group in South Africa the following method of assaying gold solutions by electrolysis has been in use for four years. Mr. C. Crichton describes it in the *Journal* of the Chemical, Metallurgical and Mining Society of South Africa, Sept., 1911. The operation is carried on in a beaker, and suitable stand is provided to hold a number of beakers. The cathode connection rod extends along the stand just in front of the beakers and slightly above their tops. At suitable intervals a flexible wire is soldered to the rod, forming a connection for the cathodes. Above the beakers extends the anode rod to which are clamped anodes of gas carbon.

The cathodes are made from ordinary lead foil, a piece 9 in. long serving for each assay. The piece is notched along one edge which is to be the bottom of the cathode, thus providing for circulation of the solution. At one end of the strip a piece about ¼ in. wide is all but severed from the strip, and turned up to form a connection with the cathode wire. The strip is then formed into a cylinder, with the notches at the bottom and the connection projecting upward.

Current is provided by three 2-volt accumulator cells giving a terminal pressure of just over 6 volts. The stronger the solution is in KCN the greater will be the amperage; for example, a solution having a strength of 0.3 per cent KCN passes 0.1 amp, and one having a strength of 0.02 per cent KCN will pass but 0.04 amp. The accumulators are charged through a direct-current lighting circuit.

Ten A. T. of solution is used for an assay, which is completed in four hours. The lead cathodes are removed, dried, and cupelled with a little silver. The button is parted and weighed, the entire operation occupying about five hours, with little attention on the part of the chemist. Precaution should be taken against having the carbon anode in contact with the solution when the current is off, as precipitation will occur on the anode. The method has given excellent results, and has occasionally been checked with the regular evaporation and precipitation methods.

Copper.

Smelting and Refining at The Great Cobar, Australia.—A complete description of the smelter and refinery of this company appeared in the *Australian Mining Standard* for Oct. 12, 19 and 26, 1911, written by Mr. Donald Clark. We abstract some of the features that are of interest.

Smelting.—There are four furnaces arranged in line of their longest axes. Dimensions, 56 in. x 240 in. at the tuyeres. The furnace hearth plate is supported on parallel rows of eight cast-iron columns, 6 in. in diameter and 3 ft. 6 in. high. The hearth plates are made of cast iron, 3 in. thick, cooled below by water circulating through 1-in. coil pipes. A layer of silica 2½ in. thick is tamped on the plates, which serve as a bedding for a 12-in. silica brick bottom. Steel water jackets are arranged in two tiers, each 10 ft. high and 4 ft. wide, with a water space of 5 in. Tuyere openings are 5 in. diameter and 1 ft. 9 in. above the silica brick bottom. The tuyeres are spaced at 11½ in. centers, 4 to a jacket, or 20 on a side. The ends of the furnace are vertical but the sides have a bosh of 7 in. in the length of the lower jackets. The charging floor is 21 ft. above the tuyere level.

The furnaces are charged at the sides, having two counterbalanced doors on each side. Slag and matte flow continuously from water-cooled cast-copper spouts in each end of the furnace. Settlers are oval in shape, 9 ft. 6 in. x 18 ft. on the two axes, having a volume of 270 cu. ft. One of these is placed at each spout of each furnace, except at the outside spouts of the end furnaces, where circular settlers are installed, 18 ft. in diameter. The settlement of matte is as complete as it is possible to make it, and slag is sent to the dump from the settlers.

The ores smelted analyze as follows:

	Cobar.	Bourke.	Chesney.
Insoluble	16.24%	80.0%	68.0%
Alumina	6.50	2.8	8.0
Iron	40.40	9.0	12.0
Copper	2.60	1.3	3.5
Sulphur	11-20	...	...

A typical charge for the first matte is as follows:

Cobar	8000 lb. to 6600 lb.
1 part Chesney, 2½ Bourke	1000 lb. to 2400 lb.
Coke	450 lb. to 800 lb.

The matte produced runs from 16 to 22 per cent copper, and the slags assay about 38 to 40 per cent silica and 50 to 53 per cent ferrous oxide.

In the concentration furnace in which matte is concentrated for converting a typical charge is:

Raw ore (Cobar)	1800 lb. to 2500 lb.
Matte	3200 lb.
Slag	1200 lb. to 2000 lb.
Coke	500 lb. to 600 lb.

Requisite amount of Bourke gold ore.

The matte from this furnace carries 30 to 38 per cent copper, and the slags assay about 40 per cent silica and 54 per cent ferrous oxide.

The matte is reduced in acid-lined converters, the lining being composed of silicious gold ore (Bourke and Chesney) and clay mechanically tamped. The converter slags contain 1 to 2 per cent copper and are resmelted in the concentrating furnace. Blister copper is poled and cast into plates 2 ft. 2 in. x 2 ft. 4 in., weighing 215 lb. each.

The electrolytic tanks at the refinery are made of Oregon pine and are 2 ft. 10 in. high, 3 ft. 2 in. wide and 5 ft. 1 in. long. They are lined with 6-lb. lead which is protected by a hardwood grating. The wood exposed to the acid solution is prepared by boiling in paraffin. The tanks are arranged in terraces of eight, with three terraces in a row. The first, ninth and seventeenth tanks are on the same level. One dynamo is provided for each row, and a separate supply of solution is fed to each terrace of tanks. From the last tank in each terrace the solution flows to a sump from which it is elevated to storage tanks by air lifts. The solutions are heated to 130 deg. Fahr., by means of steam passing through hard lead coils. At this temperature the copper is deposited in a smooth even manner, and the resistance of the bath is lessened. The circulating solution starts with a strength of 12 per cent $CuSO_4$, $5H_2O$, and 12 per cent free H_2SO_4. If it becomes too rich in copper it is electrolyzed with insoluble anodes. The cathodes are removed in about fourteen days, melted and cast into bars weighing about 32 lb. The purity of the cast copper is tested with a Wheatstone bridge. The anode sludge has the following composition:

Copper	46.8%
Gold	1.5 to 4
Silver	15.5
Bismuth	0.7
Sulphur	2.2
Selenium	0.65

It is first dried and treated with strong sulphuric acid to remove copper. The residue is smelted with silica and sodium carbonate, and the Dore bullion cast into 100-oz. anodes. These are then refined electrolytically by the Moebius process.

Fire at Carbon Factory.

A fire at the plant of the American Carbon & Battery Company, whose offices are located at 509 Olive Street, St. Louis, Mo., destroyed one of the main buildings. The loss, being estimated at between $75,000 to $100,000, was covered by insurance.

A great deal of machinery but only a small amount of the large stock of carbon brush material and general carbon products were destroyed, as most of the latter products were in a building adjoining the one that burned. Enough finished and semi-finished material is in stock to supply their trade until the plant is rebuilt. Temporary quarters have been arranged and all orders are being filled promptly.

The battery plant was not injured in any way, and work has gone ahead without any delay in this department.

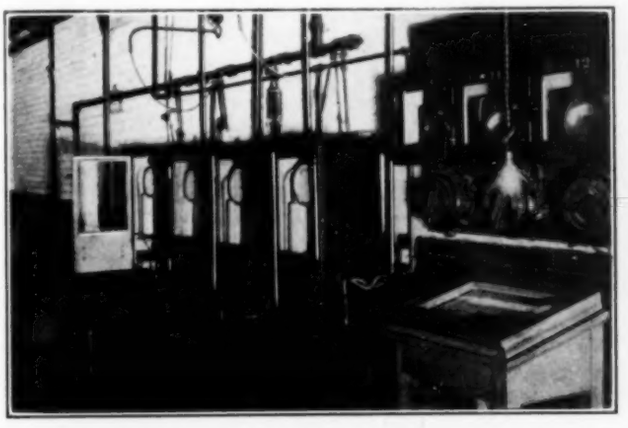
The carbon plant will be rebuilt at once, and will be of a very complete and up-to-date style. Special machinery will be put in to facilitate the manufacture of the new and improved line of motor and generator brushes which were put on the market a short time ago, and the company will continue to make the full line of standard and special carbon and graphite materials which it has heretofore produced.

Automatic Gas Analysis for Boiler House and Chemical Works Control.

In our Vol. IX, page 327 (June, 1911) a description was given of the Simmance-Abady automatic gas analyzers made by the Precision Instrument Company, of Detroit, Mich.

These are made in two types. In the first class, for non-corrosive gases, there is the precision Simmance-Abady CO_2 recorder which periodically analyzes samples of flue gas for the percentage of carbon dioxide which they contain and records this percentage on a chart. The adjoining illustration shows an installation of such CO_2 recorders, made by the Precision Instrument Company for the Solvay Process Company for a battery of twelve water-tube boilers of 279 hp rated capacity each.

In the second class are the recording analyzers for corrosive gases, such as SO_2, HCl, and chlorine gas, for use in chemical and metallurgical works, in paper mills, etc. They operate on the same general principle, but all the parts which



INSTALLATION OF CO_2 RECORDERS IN SOLVAY PROCESS COMPANY'S PLANT.

handle the gases are made, not of metal, but of glass, to withstand the corrosive action of the gas. Further, on account of the fumes from the gas, the indicating and recording mechanism is contained in an air-tight compartment.

Personal.

Mr. Gelasio Caetani, consulting metallurgist, has returned to San Francisco from a professional trip into British Columbia.

Mr. George E. Collins, consulting mining and metallurgical engineer, has been called to London on professional business. He is expected to return to Denver about Feb. 10.

Mr. Ivan E. Goodner, who is on the metallurgical staff of the Alaska-Treadwell Company, has returned to Alaska from a recent visit to San Francisco.

Mr. L. O. Howard, formerly a member of the faculty of Case School of Applied Science, Cleveland, Ohio, has gone to Green River, Utah, to take charge of operations of a company which is undertaking the development of vanadium deposits in that district.

Mr. Chas. Lindmueller is in charge of the new plant of the Goldschmidt Detinning Company at East Chicago, Ind., where they will manufacture pig tin. The plant is nearing completion and will be operating in a short time.

Mr. Henry P. Lowe, managing director of the Frontenac Mines, Ltd., Central City, Col., has just made a trip to Midvale, Utah, to inspect the operation of the Huff electrostatic separators, in successful operation there, and investigate their applicability to his ores.

Mr. L. H. Norton, consulting metallurgist of Silverton, Col., has gone to Mexico, where he will be engaged professionally until spring, when he will return to Silverton.

Mr. Richard A. Parker, of Denver, delivered the fourth in the series of "practical talks" inaugurated by the Colorado Scientific Society at Central City, Col., Jan. 13. His subject was "What a Mine and Mill Manager Ought to Know," and bore on the technical and commercial qualifications for good management.

Mr. E. P. Post, assistant in chemical department of the Carnegie Tech., Pittsburgh, has been appointed chief chemist of the Enameled Pipe & Engineering Company, Elyria, Ohio.

Mr. Georgie G. Vivian, until recently manager of the North American Smelter & Mines Company, at Golden, Col., has accepted a similar position at the Pittsmont smelter of the East Butte Mining Company, Butte, Mont.

Digest of Electrochemical U. S. Patents.

Prior to 1903.

Arranged according to subject matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Ore Treatment (*Continued*).

No. 518,711, April 24, 1894, P. C. Choate, assignor to The Electrical Zinc Company.

Zinc. Precipitates a zinc fume from complex ores, as in his preceding patents. Then heats the fume with carbon in a vertical retort having a central perforated downwardly-opening pipe. The reduced zinc, with any lead, runs into the vessel below. If much lead is present, it is separated from the zinc by gravity. The zinc is run into slabs which are used as anodes in a solution of pure zinc sulfate, containing a little sodium chlorid to precipitate any silver. The cathodes may be plates of zinc. The bath is kept in motion by pumping the overflow back. In distilling the fume, contact with iron tools, or the use of coal containing iron, should be avoided.

518,732, April 24, 1894, Parker C. Choate, of New York, N. Y., Assignor to the Electrical Zinc Company, of New Jersey.

Zinc. Treats complex ores by roasting at a temperature insufficient to volatilize the zinc, driving off the excess of sulfur, mixing with coal screening, roasting on a grate to volatilize the zinc, some lead, antimony, arsenic, cadmium, etc., collecting the fume in bags, roasting the fume at a moderate temperature to re-volatilize the metalloids, and dissolving the residue in sulfuric acid and electrolyzing. Impurities in the solution may be initially deposited upon the cathode, or chemically precipitated, including lead sulfate. Uses anodes of lead or carbon and cathodes of zinc or copper. The freed sulfuric acid overflows from the cells and is carried to tanks, where it is neutralized by purified zinc fume.

526,099, Sept. 18, 1894, Paul Danckwardt, of New York, N. Y., Assignor of One-half to Charles Doehring, of Same Place.

Gold and silver. Treats finely pulverized ores with a solution of potassium cyanid and ammonium sulfate. Two forms of electrolytic apparatus are shown: one consists of two concentric horizontal cylinders, the outer a rotating cylinder of iron lined with lead having stirring blades and serving as anode, and the inner cylinder of amalgamated sheet copper serving as cathode. The gold and silver are deposited in the amalgam, the inner cylinder is removed and the amalgam scraped off. The second apparatus consists of a series of horizontal semi-cylindrical troughs having amalgamated inner surfaces arranged in echelon, serving as cathodes. Within each tank is a revoluble cylinder serving as anode.

528,023, Oct. 23, 1894, Louis Pelatan, of Paris, France, and Fabrizio Clerici, of Milan, Italy.

Gold. Ores are crushed, the coarse gold removed by amalgamation, and the sludge fed into a series of electric amalgamators, consisting of wooden vats, in the bottom of each of which is an amalgamated copper disc, serving as cathode. A vertical shaft has stirring blades, and is surrounded by a zinc tube serving as anode. The electrolyte is a solution of potassium cyanid, not over 1/10 of 1 per cent., and of sodium chlorid or carbonate, 2 per cent. After treatment for two hours, the sludge is run off, the tailings filtered off and the gold precipitated by passing the solution through aluminum turnings.

BOOK REVIEWS.

Tables of Physical and Chemical Constants and Some Mathematical Functions. By **G. W. C. Kaye** and **T. H. Laby.** 6½ x 10 in., 153 pages. Price, $1.80 net. New York and London: Longmans, Green & Co.

A commendable collection of useful constants, not bulky or padded, not weighted down with obsolete and worthless data, but all through offering a most judicious selection of the very best. The thermochemical data given are, however, few and hardly satisfactory. Recipes for various operations, such as for silvering mirrors (p. 73), are out of place in such a work; the space should have been used in giving constants which have been omitted.

The type is well chosen to facilitate consultation, definitions are exact and up-to-date, and the work will be found in many cases an excellent substitute for the larger and more expensive collections of tables.

* * *

Electro-Analysis. By **Edgar F. Smith.** Fifth edition, 5 x 7½ in., 332 pages, 46 illustrations. Flexible leather binding. Price, $2.50. Philadelphia: P. Blakiston's Sons & Company.

Dr. Smith's book is so admittedly the standard book in English on electrochemical analysis that description or commendation is equally unnecessary.

This revised and enlarged edition contains, as new material, the essentials of all that has appeared upon electro-analysis during the past four years. Special stress is placed upon the utility of the mercury cup and the double-cup, by means of which some acids are estimated with greatest accuracy, and determinations and separations of the alkali metals are made with ease and comfort. These are very interesting examples of analytical laboratory methods borrowed in principle from industrial electrochemical processes.

Prof. Smith's book is better and more useful and illuminating than ever.

* * *

A Manual of American Mining Laws. By **A. H. Ricketts,** of the San Francisco Bar. Size, 4½ x 6½ in. (11½ x 16½ cm), 500 pages. Price, $4. San Francisco: Scientific Publishing Company.

Mining Law, for the Prospector, Miner and Engineer. By **H. W. MacFarren.** Size 5 x 7½ in. (13 x 19 cm.) 356 pages, 33 illustrations. Price, $2. San Francisco: Mining & Scientific Press.

These two works are both excellent and commendable. They do not cover exactly the same ground or treat the subject in the same way. The first is a lawyer's compendium, the information being in strictly legal language, with copious references to legal literature; it is a work of great detail, laboriously and painstakingly worked out. It will be of great service to lawyers and to others capable of understanding legal terms and forms.

The second is a reference book, with the information put in a form to be easily grasped by the layman. The author is in the mining profession, and has been a mineral examiner of the General Land Office.

Both books are attractively printed and bound.